Paley

WILLIAM PALEY. D.D.

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VOL. II.

PALEY'S NATURAL THEOLOGY,

WITH ADDITIONS FROM

LORD BROUGHAM, AND SIR CHARLES BELL,

A LIFE AND PORTRAIT OF THE AUTHOR, AND NUMEROUS OTHER ILLUSTRATIONS.

THE WHOLE NEWLY ARRANGED AND ADAPTED TO THE SCHOOL LIBRARY,

BY ELISHA BARTLETT, M. D.

IN TWO VOLS. VOL. I.

BOSTON:
MARSH, CAPEN, LYON, AND WEBB.
1839.

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AND THE

SUPPLEMENTARY DISSERTATIONS,

OF

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EDUCATION PRESS.

MEMOIRS OF THE AUTHOR,

BY THE REV. ROBERT LYNAM, A. M.,

Assistant Chaplain to the Magdalen Hospital.

William Paley, author of the following admirable volumes, was born at Peterborough, in the month of July, 1743. The day of his birth has not been preserved, but his baptism was solemnized on the 30th of August. His family was reputable and ancient, having resided for several generations in Craven, in the West Riding of Yorkshire. In this district, his great-grandfather, John, and his grandfather, Thomas Paley, enjoyed, in succession, a small patrimonial estate, at Langcliffe, in the parish of Giggleswick.

The father of our Author bore the same name, and was of the same college and profession, as his son. Having proceeded to the degree of Bachelor of Arts, at Christ's College, Cambridge, he was instituted, August, 1735, to the vicarage of Helpstone, a small benefice in Northamptonshire. His promotion to a minor canonry, in the cathedral church of Peterborough, occasioned him to fix his residence in that city; and here it was, that the subject of these memoirs received his birth. He was the eldest child, and only son; but the family was subsequently augmented by the birth of three daughters. His mother was Elizabeth Clapham, (of Stackhouse, in the parish of Giggleswick,) a woman commended for her strength and activity of mind; which qualities, as well as the benevolence of disposition ascribed to his father, her son inherited.

Although our Author, at his birth, seemed excluded from the soil on which his ancestors had long resided; yet circumstances, at an early age, transplanted him to the same northern abode. In 1745, his father resigned his minor canonry, and removed to Giggleswick, upon receiving the appointment of head-master to the Free Grammar School established there. By this change, young Paley was placed within the sphere of those local and moral associations, which are supposed to have had a strong and permanent influence upon his character. "His originality," observes one of his friends, "I apprehend, after all, must be traced to the peculiar scene of his boyhood and youth. In a spot comparatively rude and rustic, like Giggleswick, in the free and familiar acquaintance with a people of strong mother-wit and Sabine simplicity, the peculiar genius of Paley was formed, void of art, and abhorrent to all affectation." An able critic* has attributed equal power to the same cause. The inhabitants of the rugged and remote tract of Craven, have, he assures us, like other mountaineers, a character more strongly marked than their lowland neighbors, from which Paley derived an early tincture, which no intercourse with the world ever wore off, or produced an inclination to wear off. They possess clear and shrewd understandings; great humor and naïveté in their conversation, fondness for old stories, rusticity often affected, and a dialect which heightens and sets off every other peculiarity.

Amidst a people of such native originality, the mind of Paley received its earliest ideas and impressions. To his father, he was indebted, as well for the first seeds of scholastic knowledge, as for the careful infusion of moral and religious principles. No instances of remarkable precocity are related of him; although his boyhood was distinguished by a studious disposition of mind, and greater habits of reflection than are usually discovered at that age. These might be increased by his inability to join in the ordinary amusements of youth. He was ex-

* London Quarterly Review, No. xviii. p. 390

cluded from all athletic sports, by wanting in body that activity which nature had liberally bestowed upon his mind ; so that the quiet and indolent recreation of angling was the principal amusement in which he took delight. His mind was ardent, and his curiosity active, especially upon subjects of mechanical ingenuity. That attention, also, which he paid, through his whole life, to the laws of his country, and the practice of courts of justice, was early awakened in his bosom. Having been present, one year, at the assizes in Lancaster, his youthful fancy was so interested by the proceedings he had witnessed, that the solemnities of the court were reacted at school, and young Paley, assuming the dignity of a venerable judge, had his playmates arraigned before his mimic tribunal.

But the realities of life were soon to commence. Upon the completion of his fifteenth year, he accompanied his father to Cambridge, and was admitted, on the 16th of November, 1758, a sizer of Christ's College ; a society which can enumerate among its members, Milton, the sublimest of poets, and Paley, the clearest of philosophers. The journey to Cambridge, or part of it, was to be accomplished on horseback ; and our young hero, not being so skilful in keeping close to a steed, as to an argument, suffered a series of disasters, which he used himself to relate. "I was never a good horseman ; and when I followed my father, on a pony of my own, on my first journey to Cambridge, I fell off seven times. I was lighter, then, than I am now ; and my falls were not likely to be serious. My father, on hearing a thump, would turn his head half aside, and say, 'Take care of thy money, lad.'"

The year between Paley's admission, and residence, at college, was devoted to the cultivation of mathematical knowledge. As classics were the only study pursued at Giggleswick school, he was placed under the care of Mr. William Howarth, at Dishforth, near Topcliffe, in Yorkshire, for the sake of instruction in geometry and algebra. To this new field of investigation, there is no doubt that he applied himself sedulously, and with avidity. In demonstrative science, there must have been something

congenial to his logical and penetrating mind; for, notwithstanding his studies in it were commenced late, and suffered considerable interruption, for two years, at college, he was able to carry off the highest mathematical honor, which a mathematical university can confer.

His residence at Cambridge, began in October, 1759, when he had attained the age of little more than sixteen. His father seems to have formed a correct estimate of his genius, and to have indulged in hopeful anticipations, which rested on some stronger basis, than parental partiality. "My son," he observed to one of his pupils, "is now gone to college; he'll turn out a great man, very great indeed; I'm certain of it; for he has by far the *clearest* head I ever met with in my life." Paley possessed few advantages, besides his acuteness, to assist him. Adorned with no accomplishments of learning, but what a village school could supply, he was to contend with the well-trained sons of Eton, Westminster, and other public seminaries. Furnished with little experience from his intercourse with the world, he found himself, at the most dangerous age of boyish petulance, left to his own control. It was difficult, at sixteen, to resist the temptations which on all sides solicited him; inclination was to be thwarted, idleness repelled, and pleasure overcome. His uncouthness of appearance and rusticity of manners, were at first topics of merriment to the more polished collegians; these disadvantages, however, were soon overlooked in the admiration which his worth and talents excited.

It was soon discovered, that the young freshman was an agreeable and entertaining, if not an elegant companion. His powers of conversation, his facetiousness, and that invincible good-humor, which always made him willing to turn a laugh against himself, speedily drew around him, a large circle of idle and thoughtless young men. This love of society, had nearly overcome his industry, and ruined all hopes of obtaining eminence in the university. A singular occurrence, fortunately awakened reflection, and stimulated the great powers of his mind into vigorous action. "I spent," he confessed, "the

first two years of my under-graduateship, happily, but unprofitably. I was constantly in society, where we were not immoral, but idle, and rather expensive. At the commencement of my third year, however, after having left the usual party at rather a late hour in the evening, I was awakened, at five in the morning, by one of my companions, who stood at my bedside and said, 'Paley, I have been thinking what a fool you are. I could do nothing, probably, were I to try, and can afford the life I lead; you could do every thing, and cannot afford it. I have had no sleep, during the whole night, on account of these reflections, and am now come solemnly to inform you, that if you persist in your indolence, I must renounce your society.'

"I was so struck with the visit and the visiter, that I lay in bed a great part of the day, and formed my plan. I ordered my bedmaker to prepare my fire every evening, in order that it might be lighted by myself. I arose at five, read during the whole of the day, except such hours as chapel and hall required, allotting to each portion of time its peculiar branch of study; and just before the closing of gates, (nine o'clock,) I went to a neighboring coffee-house, where I constantly regaled upon a mutton chop and a dose of milk-punch. And thus, on taking my bachelor's degree, I became senior wrangler."

Nothing could be more magnanimous than Paley's resolution, except it be, the warm expostulation of his ingenuous friend. Before he could proceed to his degree, it was necessary to keep what is called an *act*, that is, to defend so many mathematical and philosophical questions in the public schools of disputation. He happened to fix upon a subject which occasioned him a little embarrassment; although he had selected it from a book usually referred to, at that time, in the university, *Johnson's Quæstiones Philosophicæ*. The most authentic account of this incident is to be found in Bishop Watson's memoirs of his own life. "The first year I was moderator," says this prelate, "Mr. Paley, (afterward known to the world by many excellent productions, though there are some ethical and some political principles in his phi-

losophy, which I by no means approve,) and Mr. Frere, a gentleman of Norfolk, were examined together. A report prevailed, that Mr. Frere's grandfather would give him a thousand pounds, if he were senior wrangler : the other moderator agreed with me in thinking that Mr. Paley was his superior, and we made him senior wrangler. Mr. Frere, much to his honor, on an imputation of partiality being thrown on my colleague and myself, publicly acknowledged that he deserved only the second place ; a declaration which never could have been made, had they not been examined in the presence of each other.

"Paley, I remember, had brought me, for one of the questions he meant for his act, *Æternitas pœnarum contradicit Divinis attributis?** I had accepted it ; and indeed I never refused a question, either as moderator or as professor of divinity. A few days afterward, he came to me in a great fright, saying, that the master of his college (Dr. Thomas, dean of Ely) had sent to him, and insisted on his not keeping on such a question. I readily permitted him to change it, and told him, that if it would lessen his master's apprehensions, he might put in *non* [not] before *contradicit*, and he did so. Dr. Thomas, I had little doubt, was afraid of being looked upon as a heretic at Lambeth, for suffering a member of his college to dispute on such a question, notwithstanding what Tillotson had published on the subject many years before."

Although Paley carried away the palm of senior wrangler, his honors, for some time, were but barren and unprofitable to him. It might have been expected, even by those who set no very high value on learning, that the youth, whom Alma Mater had distinguished as one of the first of her scholars, she would not, with parental ingratitude, have dismissed to toil in the slavery of a school. In the present day, Cambridge, no doubt, could find some more honorable and lucrative employment for a senior wrangler ; although many such scholars as the accomplished

* Whether eternal punishments are repugnant to the Divine attributes.

Gray, she would abandon, without compunction, to indigence and neglect. In 1763, even the top of the Tripos, seems to have been rather a frigid and comfortless elevation; for the first reward of Paley's labors, was only to be recommended by his tutor for the situation of second assistant, in an academy at Greenwich, kept by Mr. Bracken. The reader who delights in biography, will recollect, that similar occupations of scholastic drudgery, were filled even by Dr. Goldsmith and Dr. Johnson, two of the ablest writers in our language. But this took place before the bright talents of these great authors had emerged into notice; and their fate, though severe, is less a subject of wonder, as no university had crowned them with her dusky laurels. However, Paley was happy under circumstances, which would have made many scholars miserable. His employment was teaching the Latin language, which gave him what he stood in need of, an opportunity of improvement in classical knowledge. His chief pleasures consisted in visiting the theatres, and frequenting courts of justice; tastes which originated early, and abided with him through life. So little was he oppressed with the irksomeness of his situation, and so humble was the sphere of his wishes, that he often declared, that "the rank of first assistant in the academy, was then the highest object of his ambition."

The subject of an author's first production, usually discovers the natural bias of his genius. But the eccentricities of the human mind are innumerable, and imagination would weary itself in divining what was the early birth of Paley's talent. His first known composition, we are assured, was a *Poem in the manner of Ossian.* It is singular enough to observe the genius, which, in maturity, relished nothing but the strictest realities of truth, employed in conjuring up the shadowy spectres of imagination; the intellect of Paley, which was all light and clearness, enveloping itself in the dense mistiness of Ossian. His next literary attempt was one more correspondent to our expectations. The representatives of the university give four annual prizes of fifteen guineas each, which are adjudged by the vice-chancellor and heads of

colleges, to two senior and two middle Bachelors of Arts, who shall compose the best dissertations in Latin prose. For one of these rewards, Paley, who was a senior bachelor, offered himself a candidate in 1765. The subject was, to institute *a comparison between the Stoic and Epicurean philosophy, with respect to the influence of each on the morals of a people.* Paley gave the preference to the Epicurean philosophy; considered, of course, in its genuine purity, freed from those calumnies with which its enemies had aspersed it, and divested of those additions with which it had been encumbered by its friends. The success of the essay was endangered by the English notes that were affixed to it. These gave rise to a suspicion that the Author might have been assisted by his father, some country clergyman, who, having forgotten his Latin, had written the notes in English. Dr. Powell, master of St. John's College, gave his verdict in favor of the performance, alleging that "it contained more matter than was to be found in all the others; that it would be unfair to reject such a dissertation merely on suspicion; since the notes were applicable to the subject, and showed the Author to be a young man of the most promising abilities and extensive reading." The majority of the heads confirming this opinion, the first prize was awarded to Paley.

He showed both modesty and taste in his choice of a motto for the essay. The following words, which he selected, express the anxious feelings of many a candidate for honors.

> Non jam prima peto mnestheus, neque vincere certo,
> Quamquam O!———— ÆNEID, v. 194.*

His success was communicated to his friend Mr. Stoddart, in a letter without date or name, and the brevity of which, even a Spartan might commend. The whole of it was this: "Io triumphe!† Chamberlayne is second." He had reason to exult at his victory over Mr. Chamberlayne, as this gentleman was an eminent classical scholar,

* [I seek not now the foremost palm to gain;
Though yet—but ah!———— DRYDEN.]

† [An exclamation of joy, exultation, and triumph, like our *huzza!*]

and had gained the first member's prize in the year preceding. The brevity of Paley's epistolary correspondence is thus noticed by one of his friends. "In his younger days, he was very averse to writing letters. I have often paid a penny a line for his correspondence, relating chiefly to college business, and once a penny a word. He used to say, in his jocular manner, that 'letters to friends answered no other purpose than to show a man's wit, or to express the sincerity of his friendship. My friends,' added he, 'are well convinced that I possess both.'"

His bachelor's essay, though not distinguished for elegant Latinity, has been extolled for the vigor of thought and the justness of reasoning which it exhibited. The conclusion contains an imitation of a noble sentence of Locke's,* and pronounces a splendid but just eulogy of our Christian faith.

"Illuxit aliquando religio, cujus auctor est Deus, cujus materia veritas, cujus finis est felicitas. Religio aliquando illuxit, quæ Stoæ paradoxon in principiis verè Epicureis fundari voluit. Sufficit ad felicitatem virtus, virtutis tamen finis est felicitas. Stabile denique quiddam est in quo pedem figamus, patetque nil veterem potuisse disciplinam, nil non perfecisse Christianam." "At length there has shone upon us a religion, which has God for its author, truth for its matter, and happiness for its end. At length there hath shone upon us a religion, which, on principles truly Epicurean, establishes the Stoical paradox of the sufficiency of virtue. Virtue alone is now sufficient for our happines in this world; and yet happiness in another world is the proper end and motive of all virtue in this. We have, therefore, at last, a foundation on which we may firmly rest; and it is evident, that as, by the doctrines of ancient philosophy, little or nothing was done for the good of mankind, so nothing has been left undone for it by Christianity."

With such sentiments of admiration towards the reli-

* His words are, with respect to the New Testament, "It has God for its author; salvation for its end; and truth, without any mixture of error, for its matter."—*Locke's Works*, vol. x. p. 306.

gion he was to inculcate, Paley entered into holy orders; and served the curacy of Greenwich, under Dr. Hinchliffe, afterward bishop of Peterborough. Thinking himself injured in the distribution of some money sent by the parents of the pupils, as presents to the different assistants, he quitted the academy of Mr. Bracken.

In June, 1766, Paley was elected Fellow of Christ's College; and thus received the reward long due to his rank on the Tripos. He was now induced to become resident at the university, and to lend his assistance to Dr. Shepherd in the tuition of the college. His partner in this office was Mr. John Law, a gentleman distinguished for high attainments, and who, through life, was attached to our Author with all the cordiality of the most intimate friendship. His father was Dr. Edmund Law, master of Peter-House, who, upon his promotion to the see of Carlisle, in 1769, showed his regard for Paley, by appointing him to the station of his chaplain.

This prelate's third son, Edward, the late Lord Ellenborough, was aided in no small degree by Mr. Paley, in the successful cultivation of those talents, which raised him to the high judicial rank of Lord Chief Justice of the King's Bench. In congratulating the judge upon his rapid advancement, our Author paid him rather a quaint compliment: "Your Lordship has risen higher and sooner than any man of whom I have lately heard, except M. Garnerin," the French aeronaut.

In 1771, a circumstance took place, that called forth from Mr. Paley and Mr. Law, a display of virtuous intrepidity, which, considering their youth, no panegyrist can too warmly commend.* "When the hall of Christ's College, which had been promised through the interest of Dr. Shepherd, was fitting up for a benefit concert for Ximenes, a Spanish musician, warmly patronised by Lord Sandwich, Mr. Paley and Mr. Law peremptorily insisted that the promise should be recalled, unless satisfac-

* See Meadley's Life of Paley, which has been consulted all along for facts. In these, his accuracy has not been questioned; although every one will not be disposed to concur with him in his inferences and observations.

tory assurance was given that a lady, then living with his Lordship, and who had been openly distributing tickets, should not be permitted to attend. At first, the senior tutor, who was in habits of intimacy with Lord Sandwich, objected to the idea of excluding any lady from a public concert; but afterward, when they urged, that, standing in a public situation, as the instructers of youth, it was their duty to discountenance every sort of immorality, and threatened to appeal to the society in case of his refusal, the assurance was given, and the arrangements allowed to proceed."

In April, 1771, Mr. Paley first appeared as one of the preachers at the Royal Chapel, Whitehall. The following year, he and Mr. Law were admitted to an equal share, with Dr. Shepherd, of the emoluments as well as labors of college tuition. This was but common justice; for no tutors could be gifted with greater skill in awakening and improving the faculties of their pupils, and few ever showed such a conscientious regard to their moral purity. It was the zealous endeavor of these upright men, to repair the laxity of college discipline, to place some reasonable control upon youth, and not to allow them, just emancipated from school, and glowing with the vehemence of passion, to adjust their time and pursuits by their own blind inclination. In the distribution of the duties of the lecture-room, the mathematical department was assigned to Mr. Law; his colleague lectured upon ethics, divinity, and metaphysics. In the province of instruction, Paley excelled. He was convinced, that although his authority might collect together a certain number of young men, he should have few but listless and indolent auditors, if his art did not stimulate them to take an interest in the subjects of discussion. He used to begin, therefore, by suggesting difficulties, and exciting doubts in their minds; judging, that when their curiosity was awakened, that would impel them forward in the direction he desired. The idle and the indifferent were made to undergo a mortifying chastisement. The close, pointed, and persevering questions of the lecturer, aided by the mirth of the pupils, prepared a spe-

cies of mental torture for the ignorant, which few would be hardy enough to encounter. The metaphysical lectures began with Locke's incomparable Essay; Clarke on the Attributes, and Butler's Analogy, followed: and the abstruseness of all these books he relieved by familiar illustrations, and a free paraphrase in his own perspicuous style. In his ethical lectures he is said to have advanced the leading tenets and principles, which he afterward fully developed in his great work upon Moral and Political Philosophy. Sunday and Wednesday evenings were reserved for explication of parts of the Greek Testament; and it was his custom to recommend to theological students, the perusal of *Locke on the Reasonableness of Christianity, and on the Epistles.* Some such course of study as this, of which we have given the outline, every man of liberal education might pursue with advantage. It would invigorate his understanding, and increase his powers of thinking and judging, far better than many parts of the mathematics. It would teach him (what men of all professions are concerned to know) the general properties of his own mind, the relations in which he stands to the highest and the lowest of intellectual beings, and the indestructible basis on which he may build his hope of a complete and permanent happiness hereafter.

In June, 1774, he was separated from his coadjutor, Mr. Law, who was advanced to a prebendal stall in his father's diocese. Shortly after, our Author himself tasted the first fruits of the same bishop's patronage, being inducted, in May, 1775, to the rectory of Musgrove, in Westmoreland, a small benefice, not more than eighty pounds a year in value.

In 1776, some judicious and interesting *Observations upon the Character and Example of Christ, and the Morality of the Gospel*, were published by Paley at Cambridge. These were originally designed as a summary and appendix to the Bishop of Carlisle's Reflections on the Life and Character of our Saviour.

Mr. Paley soon availed himself of his ecclesiastical preferment, however small, for the purpose of changing his condition. This year, June the 6th, he was married

to Miss Jane Hewitt, a young lady of the city of Carlisle, who has been described as both pleasing and handsome. In relinquishing his academical duties, he might reflect with enviable satisfaction upon the conduct he had pursued in the university. A college fellowship had not been to him a post of dozing and unimproving indolence, nor tuition a selfish scheme of personal aggrandizement. He had given his approbation and support to those plans, which were suggested (though without success) for the improvement of university discipline, for diversifying the course of study, and appointing annual examinations. His own college, where his power was less controlled, he raised to an unprecedented eminence by his assiduous, upright, and skilful management. He was now to exchange the office of tutor for the less ostentatious duties of village priest; but great as the transition may seem, it was so far from injuring his comfort, that he often declared that he had passed some of the happiest days of his life at Musgrove. He was an incorrigible disciple of Isaac Walton; and the river Eden flowing near him, offered its stream for the indulgence of his amusement.

The Bishop of Carlisle's patronage, though small, descended upon him with rapidity. Before the end of this year, (1776,) he was inducted into the vicarage of Dalston, in Cumberland, the value of which was about £90 per annum. In September, of the following year, he was presented by the dean and chapter of Carlisle to a more substantial benefice, the vicarage of St. Lawrence, Appleby, which produced the annual income of about £200. Having vacated the rectory of Musgrove, he resided six months alternately at Appleby and Dalston.

Before his presentation to Appleby, he had preached in the cathedral of Carlisle, at the episcopal visitation, a sermon upon the necessity of *caution in the use and application of Scripture language*. This was afterward published: and his next work is a pleasing proof of the serious attention which he seems to have paid to the humble but important duties of a parochial minister. Those who discharge the sacred functions of religion,

find, perhaps, no part of their office more painful, at the first trial, than visiting the sick. At the moment they should guide themselves with the greatest composure, sincerity, and affection, they are most liable to be disturbed by their feelings, and lose the power of adapting their prayers and advice to the condition of different sufferers. Feeling, we may believe, such embarrassments in the exercise of his own duties at Appleby, our Author published a very serviceable manual, called, *The Clergyman's Companion in visiting the Sick.* This work, compiled from the Book of Common Prayer, and the writings of eminent divines, was at first printed anonymously, and has passed through numerous editions.

He rendered another service to the ministers of the Church, and to the junior part especially, in publishing an *Admonitory Sermon to the young Clergy of the Diocese of Carlisle, preached at a general Ordination, holden at Rose Castle, July* 29, 1781. In this discourse, the Author does not dissipate the force of his advice in loose and general exhortation: he is minute enough to be useful, descending to those particular vices which are most dangerous to the sacred profession, and enumerating the habits and qualifications which are its chief ornament. Those who are preparing for holy orders should have recourse to this work, as a correct standard by which they may examine their resolutions. Until they can hope and determine scrupulously to conform their actions to it, they should not venture to assume the gown, which they are likely to dishonor.

Every friend of merit will rejoice to see dignities and emoluments alighting upon our Author. In June, 1780, he was appointed to a prebend in the cathedral of Carlisle, productive to him of about £400 annually. His friend Mr. Law, being elevated to the Irish bench, as bishop of Clonfert, vacated the archdeaconry of Carlisle, to which Mr. Paley succeeded, in August, 1782. In the diocese of Carlisle, the archdeacon holds merely a nominal office, with the possession of a small living: all the duties of the station are performed by the chancellor. Upon the death of Dr. Richard Burn, the wellknown

author of the 'Justice of the Peace,' and who for his compilation of ecclesiastical law was made chancellor of Carlisle, Mr. Paley was advanced to the usual labors, as well as the title, of an archdeacon. This took place in the year 1785, and the union of the two dignities brought him an annual augmentation of income of about £300. The vicarage of Appleby was resigned when he became archdeacon, and his residence was partly at Dalston, and partly at his prebendal house. He accompanied his friend to his episcopal residence in Ireland, having first preached at his consecration in the Castle Chapel at Dublin. The subject which he chose was, *a distinction of orders in the Church, defended upon principles of public utility.*

Hitherto our Author had published nothing but such small and fugitive pieces, as would scarcely have made his reputation more lasting than that of hundreds of upright and learned divines, who, however useful may have been their labors, are almost entirely forgotten in a few generations. In 1785, appeared his 'Principles of Moral and Political Philosophy;' a work, alone important enough, even amidst the innumerable volumes of the English language, to rescue the writer from oblivion. Paley's modesty led him to distrust his abilities to interest the public mind in discussions, so alien to the common taste, as questions of abstract ethics. His friend, the Bishop of Clonfert, estimated his powers more justly, from his knowledge of their effects in the university. By his solicitation, that system of morals, with which Paley had fortified the minds of his pupils, was given to the world, digested and amplified amid the leisure and by the experience of its Author. When the work was ready to be committed to the press, an altercation arose about its value; Mr. Faulder, the publisher, consenting to give but £250 for what the Author thought it just to demand £300. The delay that was created, was a most fortunate circumstance for Mr. Paley; for, during the interim, a bookseller from Carlisle, calling upon Mr. Robinson of Paternoster-row, was commissioned by him to offer £1000 for the copyright. Upon receiving this proposal,

Paley wrote, with trembling agitation, to the Bishop of Clonfert, who was in London, and was intrusted with the sale of the book. "Never," he used to confess, "did I suffer so much anxious fear, as on this occasion, lest my friend should have concluded the bargain with Mr. Faulder, before my letter could reach him." The contract not having been struck, Mr. F., amazed, no doubt, as much as Tarquin at the last demand of the Sibyl, quadrupled his offer of £250, and in a short time had reason to exult at his purchase. "Little did I think that I should ever make a thousand pounds by any book of mine," was the sincere and modest exclamation of the Author.

In 1787, he was deprived of his friend and patron, the Bishop of Carlisle, who died at Rose Castle, on the 14th of August, at the great age of eighty-four. Mr. Paley, several years after, paid a tribute of respect and gratitude to his diocesan's memory, by compiling a short memoir of his life, which may be found in Hutchinson's History of Cumberland, and the Encyclopædia Britannica.

In 1790, appeared the *Horæ Paulinæ, or the Truth of the Scripture History of St. Paul evinced, by a comparison of the Epistles which bear his name, with the Acts of the Apostles, and with one another.* This work will be valued by sagacious judges as the most ingenious and original of all our Author's productions. It has been translated into the German language; but has never obtained in this country that general perusal with which Paley's larger works have been honored. This comparative neglect is to be attributed, not to the execution of the work, which is admirable, but to the subtile nature of the proof which the design admitted. Although the total result of the argument is an accumulation of evidence, that is almost irresistible; yet the proofs, singly, are established by a recondite criticism, by minute collations, and verbal peculiarities, which few have delicacy of taste enough to relish. This publication is the only one, in which Paley seems not to have adapted himself exactly to the tone of the public mind; but he is repaid

for the neglect of the many by the approbation of the few that are learned and critical readers.

It is gratifying to behold the man, whose penetrating mind could enlighten the abstrusest difficulties of philosophy, cheerfully engaged in the humblest works of utility; the writer, who could instruct divines and scholars, employed, like the amiable Dr. Watts, in reducing knowledge to the level of the most youthful capacity. In the centre of Paley's great philosophical and theological works, we meet with the following publication: *The Young Christian instructed in Reading and in the Principles of Religion; compiled for the Use of the Sunday Schools in Carlisle.* This little work, however, subjected our Author to the charge of plagiarism, and involved him in a dispute which is too amusing, from its ludicrous solemnity, not to be given in the genuine words of the combatants. Mr. Robertson, the person who thought himself injured, made the following grave appeal to the editor of the Gentleman's Magazine:*

"Thou shalt not steal."
Catechism by Paley, p. 34.

Marlborough-street, Feb. 12.

"Mr. Urban,

"When the press teems with innumerable publications in every department of literature, it is no wonder that many of them are mere compilations; the observations, arguments, and opinions of preceding writers, thrown together into one general mass, and presented to the public under some new and ostentatious title. We have volumes after volumes, collected from the works of the most eminent authors, filled with heterogeneous fragments, which distract and confound the reader's memory and imagination, and consequently leave no useful impression on the mind. Some dealers in this piratical commerce take every opportunity they can seize, for converting the works of others to their own emolument. With this view, they mangle and pillage them in an arbitrary man-

* Vol. lxii. 1792.

ner, till they have either made the original composition appear to the utmost disadvantage, or devoured it as rapaciously as the harpies devoured the provisions of Æneas and his companions.

"Though, as the author of two or three humble publications, I did not imagine that I should be exposed to piratical depredations, yet I have found myself deceived. I did not recollect, that a petty thief will steal a scraper ————. Some time after the appearance of 'An Introduction to the Study of Polite Literature,' a certain reverend gentleman, in the north, republished the greatest part of that tract for the use of Sunday Schools, and others in general. To this compilation, he has prefixed his name, and his titles of honor, William Paley, M. A., Archdeacon of Carlisle. But he has not condescended to make the *least* acknowledgement, or to offer the least apology for his plagiarism, though it constitutes the first thirty pages of his publication ; to which he has subjoined the Catechism, a few pages of Scripture, two or three prayers, some *divine songs*, and other pious *collectanea*, which would not have answered his purpose, or been saleable, without the former part.

"I think myself amply justified, in thus mentioning the editor of this disingenuous publication, as it continues to be sold (notwithstanding a *former* remonstrance) by his booksellers in Carlisle and Bond Street !* In his next edition, the conscientious Archdeacon is desired to inform his readers, how such an invasion of private property can be justified on the 'principles of moral and political philosophy.' As the ingenious young students of the floating academy are subject to penal statutes, it is but reasonable, that all pilferers in the republic of letters should be chastised, in proportion to their demerits. Your impartiality, Mr. Urban, and regard for ingenuous learning, will, I hope, induce you to give these strictures a place in your magazine ; not for the sake of the writer,

* "This fraudulent publication, entitled 'The Young Christian instructed in Reading,' &c. bears some appearance and symptoms of guilt in its front. No London bookseller's name, though published in the metropolis !"

but for the most important purposes,—the discouragement of plagiarism, and protection of literary property.

"Yours, &c. J. ROBERTSON."

"Carlisle, May 18, 1792.

"Mr. Urban,

"In the Gentleman's Magazine for February, p. 131, I am accused by the Rev. Mr. Robertson of invading his property in a certain work, published by him under the title of 'An Introduction to the Study of Polite Literature.' As you have thought proper to admit into your miscellany Mr. Robertson's complaint, I expect, from your regard to justice, that you will find a place for my answer. Your readers, then, must first of all be told, what, from the air of importance which is given to the charge, they would not readily imagine, that this same 'Introduction to the Study of Polite Literature,' is a spelling-book; that one entire page of the original, for the crime of purloining which I am thus brought before the public, is verbally and literally as follows:

LESSON III.

A bag	A cap	A mat
A nag	A map	A hat
A bun	A nut	A spy
A gun	A hut	A fly

and that, except some short directions for reading, all the pages taken by me are of the same kind with this specimen, proceeding, as is the manner of primers and spelling-books, from words of one syllable to words of more, and from polysyllables to sentences of different lengths. I mention this, not to detract from the merits of Mr. Robertson's performance, which is a very good one of the sort, but in order to show that reputation of authorship could hardly be my motive for the theft. The truth and the whole truth of the transaction is this: About seven years ago, when Sunday Schools were first set up in Carlisle, I was desired to prepare some small tracts which might be put into the hands of the children and the masters. The point aimed at, was, to afford as much instruction for as little money as possible. With this

view, it was necessary to make one part answer the purpose of a spelling-book, and the other to contain the elements of religious knowledge. I executed the office of a compiler in the first part, by marking out to the printer some pages of an anonymous spelling-book, which had accidentally come into my hands as a present to one of my children. In the second part there is nothing of my own, except a piece of four pages, entitled, 'A short History of our blessed Saviour Jesus Christ.' The rest, is made up of portions of Scripture, selected by me, chiefly from the Gospels, an old tract of Lord Chief Justice Hale's, two prayers, two hymns of Dr. Watts's, a piece of Dr. Stonehouse's, taken from the Society's tracts, and another of Mr. Gilpin's. These two last-named gentlemen have not complained, probably, indeed, continue ignorant, of the injury that has been done them. Should they come to know it, I am persuaded that, instead of resenting the liberty which I have taken with their pious writings, they will rejoice to find them made, in any shape, or by any hand, useful and accessible to the poor. My name as the *compiler*, (for that is the word employed,) was placed in the title-page, because the bookseller refused to print the book without it; and it is placed there in the manner, so far as I know, commonly adopted by clergymen, for I am conscious of no affectation upon that head.

"Such was the birth of the little compilation which has provoked this angry attack. A few months after it had been printed, Mr. Faulder, of Bond Street, asked my leave to put forth an edition of it in London. I told him the first part was taken from a work, which, as I now understood, though I did not know it at the time, had been published by Mr. Robertson, of Marlborough Street; and that he must apply to Mr. Robertson for permission. Mr. Faulder made his application, and was refused; and, upon that refusal, by my positive injunction, desisted from his design. If it has been printed and sold in London, or any where else, except in this neighborhood, since that time, it is entirely without my participation or knowledge.

"Mr. Robertson says, that the collection 'would not *have answered my purpose*, or been saleable without the former part.' What purpose had I, to be answered, but that, which is expressed in the title-page—'the Use of the Sunday Schools in Carlisle?' I never gained a penny by the publication: so much otherwise, that I paid the publisher his full price for every copy that I gave away. I am at this moment ready to convey to Mr. Robertson, or his assignee, my title, if he thinks I have any, to the work, and all interest in it, whatsoever.

"Mr. Robertson has not said that the sale of one copy of his book has been hindered by the appearance of mine. From the different quality of the articles, I am convinced that no such effect can follow. His is a fair volume, a beautiful type, and a fine paper, adapted, in all respects, to the use of genteel boarding-schools, and the nurseries of genteel families. Of all the low-priced helps to education with which parish children and charity-schools were ever furnished, mine, in these particulars, is the meanest. The two books, therefore, are calculated for a totally different description of purchasers. They can never meet in the market; no person who would buy his book would be content with mine.

"This is my defence; but a part of my story is yet untold. Not long after this little book was published, and as soon as I knew Mr. Robertson's sentiments about it, the substance of what I have here alleged was drawn up by me in terms as respectful as I could frame them, and, being so drawn up, was communicated to him by a friend to us both. Although I did not believe that I had injured his property, I was truly sorry that I had offended, and that also unknowingly, a gentleman with whom I possessed a slight degree of acquaintance, whose hard fortune in his profession I have often lamented, and whose literary merits entitle him to regard, from every scholar. Mr. Robertson ought not, therefore, to have said 'that I have not condescended to make the least acknowledgement, or offer the least apology, for my plagiarism.' I did offer an apology, not indeed in print, which, I doubt not, is what he means, but by a mode of

correspondence which, in my judgement, much better became both the subject and the parties.

"And this, Mr. Urban, leads me to express my regret, that there should be one column in the Gentleman's Magazine which hath no employment more worthy of it than to convey to the public, what the public have no concern in,—a beggarly dispute about a few pages of a spelling-book, by the stealing of which, (for so let it be called,) neither the plagiarist hath gained, nor the proprietor lost, a fraction of a farthing.

"Yours, &c. W. PALEY."

This year, 1792, Mr. Paley was presented, by the Dean and Chapter of Carlisle, to the vicarage of Addingham, near Great Salkeld, the value of which was about £140 a year.

Although Mr. Paley had lost his friend, Dr. Edmund Law, he still found a friend in the Bishop of Carlisle. Dr. Vernon,* while in possession of that northern see, offered him the vicarage of Stanwix, which was accepted; and Dalston in consequence resigned. Paley, with characteristic frankness, thus explained his motive to a clerical friend: "Why, sir, I had two or three reasons for taking Stanwix in exchange; first, it saved me double housekeeping, as Stanwix was within twenty minutes' walk of my house in Carlisle; secondly, it was fifty pounds a year more in value; and thirdly, I began to find my stock of sermons coming over again too fast."

Early in the year 1794, his *View of the Evidences of Christianity* was given to the public. In this luminous and comprehensive work, the historical evidence for the authenticity of the Scriptures, selected from the volumes of Dr. Lardner, is arranged with clearness, and stated to the reader with the utmost force and precision. Many persons are wearied into impatience by the number of pages he has occupied in proving the sufferings of the first propagators of Christianity. But, as this fact is the basis of the work, it was requisite that it should be un-

* Afterwards Archbishop of York.

deniably established : superfluity of proof may be tedious, but deficiency would have been fatal. To those who shrink from the labors of weighing the detail of historical evidence, the last two parts of the work will be more interesting than the first. It is impossible to rise from a careful perusal of the whole, we will not say, without conviction, (for that may be impeded by many obstructions in the reader's mind,) but without feeling a sincere admiration of the tenets of Christianity, and the character of its Founder; and without being impressed at the time with this sentiment, That, however miraculous the truths of our religion may appear, we must assent to propositions equally miraculous, before we can conclude it to be false.

No one can accommodate a system of evidences to the doubts, capacity, and indolence of every skeptic. The antecedent credibility of miracles is, perhaps, a difficulty that has struck every reflecting mind. Upon this subject, Paley's 'Preparatory Considerations,' in which he exposes the sophistry of Mr. Hume, deserve the most serious perusal. Those who will not submit to read the numerous pages which follow, (for men who are most petulant in their doubts, seldom display much patience in attempting to resolve them,) will find the question of religion brought to a narrow issue, in Leslie's *Short and Easy Method with the Deists.* When the advocates of infidelity have logically answered this epitome of evidence, the whole of which is comprised in less than forty pages, the world will be ready to acknowledge their claim to that character of superior penetration, which they arrogantly assume.

The publication of the 'Evidences' was most beneficial to the Author : it dissolved, instantaneously, the coldness of Episcopal reserve which Paley had hitherto experienced. The writer of the 'Moral Philosophy' and the 'Horæ Paulinæ,' seemed to possess substantial claims upon the hierarchy, which is invested with patronage solely for the remuneration of learning and piety: but the freedom of some of Paley's sentiments might, for a time, perplex the most conscientious prelates, and make them hesitate

how far it was expedient to bestow upon him any conspicuous marks of ecclesiastical favor. The appearance of the 'Evidences' overcame all scruples; and minor discrepancies of opinion were sacrificed, in admiration of his steady zeal and unrivalled talent in defending the cause of revealed truth. Dr. Porteus, the learned and amiable Bishop of London, was the first to reward the advocate of religion by instituting him, in August, 1794, to the prebend of St. Pancras, which is one of the most valuable in the cathedral of St. Paul's. In January, of the following year, he was elevated to the sub-deanery of Lincoln, by Dr. Pretyman, Bishop of that diocese. This was a valuable piece of preferment, producing about &700 a year. Another, as lucrative, soon followed, from the Hon. Dr. Barrington, afterwards Bishop of Durham; who, without solicitation, generously presented to our Author, who was a stranger to him, the rectory of Bishop-Wearmouth. When, full of gratitude, Paley waited upon his benefactor to express his sincere acknowledgements; "Not one word more of this, sir, (exclaimed the noble prelate;) be assured, that you cannot have greater pleasure in accepting the living of Bishop-Wearmouth, than I have in offering it to you." The prebend of Carlisle, and the vicarage of Stanwix being vacated, Dr. Vernon relinquished his right of presentation to the first in favor of the Bishop of Lincoln, and to the other in favor of the Bishop of Durham. Thus four distinguished prelates came forward, almost simultaneously, in order to reward talent, and dignify virtue.

With his new dignities, our Author assumed a new title. He took his degree of Doctor of Divinity in the year 1795, and preached the commencement sermon, before the university, upon the dangers incidental to the *Clerical Character*.

Dr. Paley was inducted into the living of Bishop-Wearmouth, on the 14th of March, 1795. Resigning his chancellorship, the vicarage of Addingham, and whatever duties required his presence in the diocese of Carlisle, he made his principal abode at his new rectory. Three months, in every year, he was obliged to reside

at Lincoln, in his dignity of sub-dean. He was now in possession of every thing that could gratify his taste, and give comfort and serenity to his declining years. His parsonage-house and grounds at Bishop-Wearmouth were commodious and agreeable: his income was large enough to allow him to indulge in every liberal wish, and his bright and well-earned reputation would be to him a constant source of pleasing recollections. To confirm his tranquillity, and exclude any cause of acrimony and contention with his parishioners, he accepted, for life, an annual compensation, of £700 a year, for his tithes. His glebe-lands, together with a limestone quarry, were let much below their value: so that, notwithstanding his benefice was estimated at £1200 a year, it probably did not produce to him above two-thirds of that sum.

Unwilling to enjoy his good fortune without participation, Dr. Paley married a second time, on the 14th of December, 1795. His first wife died in May, of the year 1791, leaving an issue of four sons and four daughters. His second lady was Miss Dobinson of Carlisle. He now often indulged in social visits, both at Bishop-Wearmouth and at Lincoln. He acquitted himself in the duties of hospitality, liberally, but without ostentation; for, though his disposition made him enjoy society, with zest, his prudence restrained him from being injured by its splendor, or embarrassed with its frivolity.

In the midst of private pleasures, he undertook to discharge a public function of a nature entirely new to him. By the request of the Bishop of Durham, he consented to enrol himself on the commission of the peace, and assume an office, for which he was eminently fitted, both by his natural sagacity and legal knowledge. His temper, however, in the duties of a magistrate, appears not to have been equal to his other qualifications; for he has been condemned, we know not how justly, for too much warmth and irascibility. An effort which he made, for the greater purity of public morals, deserves much commendation. To check intemperance, and habits of prodigality among the lower orders, he attempted to diminish the number of public-houses, and to introduce more

caution in the granting of licenses. His laudable wishes were frustrated, not from any want of zeal on his part, but from not being seconded by the due cooperation of the other magistrates.

Dr. Paley enjoyed the gratification of having both his parents witnesses of his literary fame and honorable success in life. His mother did not die, till the year 1796; the father, who had predicted the eminence of his son, still later.

Dr. Paley soon received a severe intimation, that the son was hastening to the tomb, after the father. In the year 1800, a violent nephralgic disorder, attended with melæna, incapacitated him for the performance of his clerical duties. He was seized with a second attack, the following spring, at Lincoln, and in 1802, his complaint disabled him from keeping his usual residence in that city. He was persuaded to have recourse to the waters of Buxton; and the moments allowed him by every intermission of pain, he cheerfully devolved to the completion of his last work, his 'Natural Theology.' Dr. Fenwick, of Durham, in his *Sketch of the professional Life and Character of Dr. Clarke*, has given the warmest testimony to the fortitude of our Author.

"That truly eminent man was then engaged in finishing his 'Natural Theology;' but the completion of that great undertaking was frequently interrupted by severe accessions of a painful disorder, under which he had long labored, and which has since proved fatal. Dr. Clarke often expressed his admiration of the fortitude with which he bore the most painful attacks; and at the readiness, and even cheerfulness, with which, on the first respite from pain, he resumed his literary labors. When it is considered that the twenty-sixth chapter of his work was written under these circumstances, what he has said of the *alleviation of pain* acquires additional weight. It is not a philosopher, in the full enjoyment of health, who talks lightly of an evil, which he may suppose at a distance. When Dr. Paley speaks of the power which pain has '*of shedding a satisfaction over intervals of ease, which few enjoyments exceed;*' and assures us,

'that a man resting from severe pain is, for the time, in possession of feelings which undisturbed health cannot impart;' the sentiment flowed from his own feelings. He was, himself, that man; and it is consolatory, amidst the numerous diseases to which the human frame is liable, to find how compatible they are with a certain degree of comfort, and even enjoyment. Something may, indeed, be attributed, in Dr. Paley, to a vigor of intellect, which is allotted to very few; but it cannot be doubted, that resignation in suffering is less the gift of great intellectual powers, than of well-regulated religious and moral sentiments."

The work, thus concluded amidst the anguish of a painful disease, was published, in 1802, with the title of *Natural Theology; or Evidences of the Existence and Attributes of the Deity, collected from the Appearances of Nature.* This disquisition, alone, (he reminds us,) was wanted to make up his works into a system, in which works the public have now before them, the 'Evidences of Natural Religion,' the 'Evidences of Revealed Religion,' and an Account of the Duties that result from both. His Theology may be classed among the most interesting books of the English language. We are carried by the Author, with unceasing delight, through the most prominent wonders and striking contrivances of the whole creation. Where indolence, before, saw nothing to admire, it suddenly discovers the most ingenious designs, and elaborate workmanship; where apathy beheld no cause for affecting sentiments, it sees the most powerful reason to kindle with gratitude, and be awed with reverence to the Deity. It is a small objection to urge, that, in his discussions upon the human frame, Dr. Paley is not, according to the modern discoveries of science, always anatomically correct. Truth does not require that any of his conclusions should be retracted on account of this inaccuracy. His arguments against the atheistic schemes cannot be overthrown, even though some of his physiological descriptions may be disputed. If he had been a better anatomist, his reasonings in proof of a Deity would have been even more forcible than at present; because all the improvements in the knowledge of our own bod-

ies, tend to unfold more and more the curious subtilty of their mechanism. For those, who do not study the human structure professionally, Paley's delineation is sufficiently correct: others, who are required to be rigid anatomists, will obtain from his book something more interesting than technical knowledge; and they will be delighted with acute reflections, and devout speculations upon universal nature.

Dr. Paley's constitution was gradually yielding to the encroachments of sickness. After his return from Lincoln, to Bishop-Wearmouth, in the spring of 1805, he was seized with a violent attack of his disorder, which all art and assiduity were unable to repel. None of his faculties were destroyed during his sickness, except, perhaps, his sight, which, it is believed, failed him a few days before his decease. His sufferings did not overcome his fortitude, nor disturb his composure of mind; but, during the whole scene of his last trials, he maintained the greatest serenity and self-possession. He soothed the distress of his family, with those consolations of religion which supported himself, and, on the evening of the 25th of May, tranquilly expired. His remains were deposited near to those of his first wife, in the cathedral of Carlisle, with this humble inscription:

Here lie interred,
The remains of
William Paley, D. D.
Who died May 25, 1805,
Aged 62.

For those, who delight to be acquainted with the physiognomy, as well as the mind, of an author, the portrait of Dr. Paley, by Romney,* taken after he was appointed Archdeacon of Carlisle, will convey a correct idea of his countenance. In person, he exceeded the common stature, with a tendency, in the latter part of his life, to corpulence.

He is supposed to have left his family in affluent circumstances; for his income, during many years, had been

* An engraving from which will be found in this volume.

ample, the profit of his writings must have been considerable, and, though free from parsimony, he had always practised, what he recommended to the young clergy of his diocese, economy upon a plan. His eldest son, William Paley, rivalled his father in his successful career at college, being third wrangler, and first members' prizeman, both as middle and senior bachelor. He was a barrister of Lincoln's Inn, was distinguished for his abilities, and died in March, 1817, in the thirty-seventh year of his age.

Dr. Paley's sermons on general topics, were published after his death, under the following circumstances. In a codicil to his will, he remarked, "If my life had been continued, it was my intention to have printed, at Sunderland, a volume of sermons, about five hundred copies, to be distributed gratis, in the parish; and I had proceeded so far in the design, as to have transcribed several sermons for that purpose, which are in a parcel by themselves. There is also a parcel from which I intended to make other transcripts; but the business is in an imperfect, unfinished state; the arrangement is not settled, further than that I thought the sermon on Seriousness in Religion should come first, and then the doctrinal sermons; there are also many repetitions in them, and some that might be omitted or consolidated with others." He proceeded to direct, that, after the necessary revision of the manuscripts, the sermons should be printed at the expense of his executors, by the Rev. Mr. Stephenson, and distributed in the neighborhood, first, to those who frequented church, then to farmers' families in the country, and lastly, to such, as had persons in the family who could read, and were likely to read them; but he added, peremptorily, that they should not be published for sale. His request was complied with, as far as was practicable. A collection of the sermons was printed at Sunderland, in 1806, and given to the inhabitants of Bishop-Wearmouth; but, as it seemed impossible to prevent a surreptitious sale, his family afterward consented to their publication.

Having related, as succinctly as possible, the principal

occurrences in the life of Dr. Paley, it only remains for us to take a general view of his character. This is a gratifying task; for the history of few men presents so many topics for admiration, and so little ground for censure; such high intellectual talents, dignified with so much strict and unassuming virtue. His whole conduct, free from the bias of interest or caprice, was guided by the soundest principles of integrity, from which he deviated as little as the fallibility of our nature will allow. Such was the rectitude of his behavior, that the Rev. Mr. Hall, one of his college friends, declared, that he never knew him guilty of a vicious act, nor inattentive to propriety of moral conduct; and his first patron, Bishop Law, always gave him the eulogy of being a good man, and a good Christian. His independence was inflexible. He never relied upon any arts for his advancement in life, except the conscientious discharge of his duties, and the exercise of his talents for the common benefit. To the mode of seeking preferment by obsequiousness and servility, (which he emphatically called *rooting*,) he always expressed the most hostile antipathy. He warned the young clergy of his diocese from the pulpit, that for once patronage is forfeited by modesty, it is ten times lost by importunity and intrusion. All his own promotions in the Church were either marks of the esteem of private friendship, or testimonies of the advantage which had accrued to the cause of religion from his writings.

Although his virtue was unimpeachable, he was an enemy to all kinds of moroseness and austerity. In every relation in life, either as father, husband, or friend, he was not only exemplary for the correctness of his demeanor, but amiable for a generous warmth of feeling, and a liveliness of disposition. It was one of his apophthegms, that "a man who is not sometimes a fool, is always one." This reminds one of Rochefoucault's maxim, "Gravity is a mysterious carriage of the body, invented to cover the defects of the mind." The grave man may choose the description of his character either from the English or the French philosopher. Paley accuses him of stu-

pidity, Rochefoucault of knavery; and it is unquestionable, that from one source or the other proceeds that grave and puritanical solemnity, which passes with vulgar judges for superior wisdom and piety. Paley was never grave but upon grave occasions. In company his vivacity exhilarated all around him.

The cheerfulness, which our Author could so agreeably diffuse amongst others, he enjoyed perpetually in his own mind. He was invincibly contented; nothing could depress him into gloom and despondence. Nor did this disposition proceed from an unthinking insensibility to evil, but from the discipline with which he had subjected his desires, and that pious intuition with which he saw, in the benevolent contrivances of the Deity, unceasing cause for grateful recollection, and joyous anticipations. Discontent and ambition are put to the blush, when we read that this highly-gifted man was happy in the toil of a school, and the indigence of a living worth only £80 a year. Subsequently, when his fame was established, and admiration was loud in her panegyrics of his merit, he was not elated into arrogance, nor seemed to think, as some of his friends did, that his rewards had been insufficient. He gratefully acknowledged to the Bishop of Durham,* that his munificence, in conjunction with some other excellent prelates, had placed him in ecclesiastical situations, *more* than adequate to every object of reasonable ambition.

In the performance of all his clerical duties, he was regular, assiduous, and devout. The labors of college tutor, and the studies of philosophy, had not given such a learned bias to his understanding, as to create any distaste for the humblest duties of an ecclesiastic. He was loved by his parishioners, for his obliging civilities, for the manner in which he adapted himself to their capacities, and sympathized with their feelings. He left them no inconsiderable token of his personal regard, and of his solicitude for their religious improvement, in the posthumous donation of his sermons. As these compo-

* Dedication to 'Natural Theology.'

sitions were never designed for publication, it would be unfair to make any comparison between them and similar works of other divines. In polished eloquence, in sublimity of description, in tenderness of sentiment, no one who considers the congregation to which they were delivered, can expect they should excel. Still the public would have had cause for regret, if they had been withheld ; for they are cogent and convincing discourses, unveiling the human heart, exposing its subterfuges, and forcing men, if they are not utterly disingenuous, to reflect with seriousness upon religion. The effect of his sermons was partly aided, partly obstructed, by his delivery ; for, though he was not free from a provincial dialect, and his voice was harsh and unmodulated, yet he was able to impress his auditors by the energy and obvious sincerity of his manner. His sentiments upon religion were mild and tolerant, and his bosom not heated with animosity against any of the sects that divide the country. As to the charge of heterodoxy, (which people often attach to others, without knowing their own or their neighbor's creed,) let those who can, substantiate it against Paley from his works ; for it is manifestly unjust now to infer it from any thing else.

In our last province, which is to estimate the literary and intellectual character of Dr. Paley, we have the concurrent testimony of all parties, that he was not encumbered with erudition, but was far from being what is termed a learned man. In classical studies he never delighted, and never made any considerable advances : for that array of learning which glitters through his 'Evidences,' was all prepared for him by Lardner and other scholars. Instead of perusing a multiplicity of books, he relied upon the fecundity of his own mind, and the acuteness of his observation, aided by some choice assistances, of which he never scrupled to make the most liberal use. What he remarked of Mr. Fox, is applicable to himself, to Dr. Johnson, and numbers of intelligent men, who think much more deeply than they read. "Why, sir, some men are never idle, and Mr. Fox is one of these : whether engaged in business, in

study, or in dissipation, his mind is actively employed. Such men lose no time, they are always adding to their stock of information; whilst numbers, with grave appearance, trifle life away, and pursue nothing with advantage or effect." Paley's chief merits as an author are, his close investigation of truth, and his clear developement of it to others. He detects it with the most acute penetration, amidst numberless perplexing errors: he disentangles it of every besetting difficulty, arranges it in the clearest method, expands it through all its proper ramifications, and illustrates it so forcibly, that it becomes as intelligible to the reader as to himself. His writings resemble a beautiful and productive orchard: we are never compelled to regale upon leaves, where we came to search for fruit. In matter, he is almost as pregnant as Aristotle, but he never repels us with the dry and uninteresting style of the Stagyrite. On the contrary, his manner, is always captivating, his language, easy, familiar, and sometimes eloquent. He often, for the sake of force, uses a quaint phraseology, and, like Socrates, employs homely illustrations and comparisons, which, though they detract from elegance, throw light, where light is most wanted.

It is often urged in disparagement of Paley's genius, that his most important works are far from being completely original. This charge is not to be denied, nor yet does it carry so much weight as envy would be inclined to attribute to it. In his 'Moral Philosophy,' he derived very essential aid from the speculations of Abraham Tucker,* a gentleman who published, under the assumed name of Edward Search, a work, in nine vol-

* Let not this ingenious writer be disparaged, though he has never had the fortune to be popular. The Quarterly Review (No. 18, p. 397) remarks, "There are some writers of great but disorderly understandings, unable to arrange, to *amplify*, or to *illustrate* their own conceptions. Such was Abraham Tucker." Paley observes, (Pref. to 'Moral Philosophy,') "I have found in this writer, more original thinking and observation upon the several subjects that he has taken in hand, than in any other, not to say, than in all others put together. His talent also for *illustration* is *unrivalled*. But his thoughts are *diffused through a long*, various, and irregular work." There can be no doubt that Paley knew Tucker's character better than the reviewer.

umes, called 'The Light of Nature.' In the 'Evidences of Christianity,' he freely availed himself of Dr. Lardner's 'Credibility of the Gospel History,' and Bishop Douglas's 'Criterion of Miracles;' and the labors of Ray, Derham, and others, furnished him with many materials for his 'Natural Theology.' When we have extracted from his works all that is the property of others, there will remain original matter enough upon which to build a just fame of authorship: and even what he has borrowed in his 'Philosophy' and 'Theology, often comes from him, and from its first authors, as different in appearance, as gold from the hands of a skilful artist, and gold in the rugged ore. His exhibition of truth is more valuable than others' discovery of it; as in manufactures, the workmanship often costs more than the article in its natural state.

It is a just rule in criticism, always to weigh an author's end, and if that be a good one, to applaud or condemn him according to his accomplishment of it, or his failure. If it was Paley's object to give a view of our moral duties, and of the proofs of natural and revealed religion, nobody can justly find fault with his design. How far he has succeeded in the execution, we may judge, by asking, what prudent man, however great his abilities, would venture to run over the same ground of discussion that Paley has occupied? If our Author consulted preceding writers, it was not for the purpose of fraudulently enriching himself at their expense, but with a view to give his own work that perfection which theirs had not attained. If former productions of the kind had possessed due excellence, his would have been superfluous; for him to follow others over difficult topics without aiding himself by their labors, would have been a proud conceit, that must have precipitated him into error, and repaid his efforts with public neglect. We may estimate the value of his works, by considering what would be our loss, if they were obliterated from the English language. How many, upon questions of casuistry that daily arise, would have had recourse to the 'Light of Nature,' the rays of which are dissipated over the surface of nine volumes?

Would shallow skeptics have been patient enough to travel through Lardner's voluminous works, in order to satisfy their doubts, when the love of truth is not so deep in most, as to carry them carefully to the end of Paley's compendious work? Would general readers have been content to pursue a detail of technical anatomy and physical phenomena, if the topics had not been illustrated and enlivened by our Author's masterly pen? In what we have said, we intend no injurious censure upon writers, from whom Paley has drawn much assistance. Persons of strong intellect, and patient industry, may find delight in Tucker. Lardner's work, is a noble monument to the truth of our religion; and Ray and Derham, in their days, were ingenious writers, and are still sometimes useful to professional men. But the patience of ordinary readers is soon exhausted by delay, and they cannot submit to lose time in tedious research. They demand, imperatively, that truth be submitted to them in the clearest light, and most compendious bulk. This, Paley has done systematically, in a beautiful series of investigation. As he has left us in private life an example that may animate the diligence and piety of every one in his profession; so he has bequeathed writings, in which all the intelligent part of his countrymen, without distinction of ranks and occupations, may see clearly unfolded the maxims of moral order, the sublime wonders of nature, the irrefragable truth and heavenly precepts of Revelation.

R. L.

NATURAL THEOLOGY.

CHAPTER I.

STATE OF THE ARGUMENT.

In crossing a heath, suppose I pitched my foot against a *stone*, and were asked how the stone came to be there, I might possibly answer, that, for any thing I knew to the contrary, it had lain there for ever; nor would it, perhaps, be very easy to show the absurdity of this answer.*

* The argument is here put very naturally. But a considerable change has taken place, of late years, in the knowledge attained even by common readers, and there are few who would be without reflection "how the stone came to be there." The changes which the earth's surface has undergone, and the preparation for its present condition, have become a subject of high interest; and there is hardly any one who now would, for an instant, believe that the stone was formed where it lay. On lifting it, he would find it rounded like gravel in a river: he would see that its asperities had been worn off, by being rolled from a distance in water: he would perhaps break it, look to its fracture, and survey the surrounding heights, to discover whence it had been broken off, or from what remote region it had been swept hither: he would consider the place where he stood, in reference to the level of the sea or the waters; and, revolving all these things in his mind, he would be impressed with the conviction, that the surface of the earth had undergone some vast revolution.

Such natural reflections lead an intelligent person to seek for information in the many beautiful and interesting works on geology that have been published of late years. And by these he will be led to infer, that the fair scene before him, so happily adapted for the abode of man, was a condition of the earth resulting from many successive revolutions taking place at periods incalculably remote; and that the variety of mountain and valley, forest and fertile plain, promontory and shallow estuary, formed a world suited to his capacities and enterprise.

So true is the observation of Sir J. Herschel, "that the situation of a pebble may afford him evidence of the state of the globe he inhabits, myriads of ages ago, before his species became its denizens."—Eng. Ed.

But suppose I had found a *watch* upon the ground, and it should be inquired how the watch happened to be in that place, I should hardly think of the answer which I had before given,—that, for any thing I knew, the watch might have always been there. Yet why should not this answer serve for the watch as well as for the stone? why is it not as admissible in the second case as in the first? For this reason, and for no other, viz., that, when we come to inspect the watch, we perceive (what we could not discover in the stone) that its several parts are framed and put together for a purpose, *e. g.*, that they are so formed and adjusted as to produce motion, and that motion so regulated as to point out the hour of the day; that, if the different parts had been differently shaped from what they are, of a different size from what they are, or placed after any other manner, or in any other order than that in which they are placed, either no motion at all would have been carried on in the machine, or none which would have answered the use that is now served by it. To reckon up a few of the plainest of these parts, and of their offices, all tending to one result. We see a cylindrical box containing a coiled, elastic spring, which, by its endeavor to relax itself, turns round the box. We next observe a flexible chain (artificially wrought for the sake of flexure) communicating the action of the spring from the box to the fusee. We then find a series of wheels, the teeth of which catch in, and apply to, each other, conducting the motion from the fusee to the balance, and from the balance to the pointer, and, at the same time, by the size and shape of those wheels, so regulating that motion as to terminate in causing an index, by an equable and measured progression, to pass over a given space in a given time. We take notice that the wheels are made of brass, in order to keep them from rust; the springs of steel, no other metal being so elastic; that over the face of the watch there is placed a glass, a material employed in no other part of the work, but in the room of which, if there had been any other than a transparent substance, the hour could not be seen without opening the case. This mechanism being observed, (it requires indeed an examination of the instru-

ment, and perhaps some previous knowledge of the subject, to perceive and understand it; but, being once, as we have said, observed and understood,) the inference, we think, is inevitable, that the watch must have had a maker: that there must have existed, at some time, and at some place or other, an artificer or artificers who formed it for the purpose which we find it actually to answer; who comprehended its construction, and designed its use.

I. Nor would it, I apprehend, weaken the conclusion, that we had never seen a watch made; that we had never known an artist capable of making one; that we were altogether incapable of executing such a piece of workmanship ourselves, or of understanding in what manner it was performed; all this being no more than what is true of some exquisite remains of ancient art, of some lost arts, and, to the generality of mankind, of the more curious productions of modern manufacture. Does one man in a million know how oval frames are turned?* Ignorance of this kind exalts our opinion of the unseen and unknown artist's skill, if he be unseen and unknown, but raises no doubt in our minds of the existence and agency of such an artist, at some former time, and in some place or other. Nor can I perceive that it varies at all the inference, whether the question arise concerning a human agent, or concerning an agent of a different species, or an agent possessing, in some respects, a different nature.

II. Neither, secondly, would it invalidate our conclusion, that the watch sometimes went wrong, or that it sel-

* It is certainly a thing not easily expressed in words. The nave of a circular wheel moves on a single pivot; but there are here two pivots, and grooves in the wheel to correspond with them. These two grooves cross each other, and play upon the pivots in such a manner that the centre of motion varies, and the rim of the wheel moves in an ellipsis. It is exactly on the same principle that we draw an oval figure, by driving two nails into a board, and throwing a band round them, and then running a pencil round within the band. These two nails are in the points called by mathematicians the *foci* of the oval or ellipse; and accordingly, a fundamental property of the curve is, that the sum of any two lines whatever, drawn from the two *foci* to any point in the curve, is always the same. These points are called *foci*, *fires*, because light reflected from the surface of an oval mirror is concentrated there and produces heat.—ENG. ED.

dom went exactly right. The purpose of the machinery, the design, and the designer, might be evident, and, in the case supposed, would be evident, in whatever way we accounted for the irregularity of the movement, or whether we could account for it or not. It is not necessary that a machine be perfect, in order to show with what design it was made: still less necessary, where the only question is whether it were made with any design at all.

III. Nor, thirdly, would it bring any uncertainty into the argument, if there were a few parts of the watch, concerning which we could not discover, or had not yet discovered, in what manner they conduced to the general effect; or even some parts, concerning which we could not ascertain whether they conduced to that effect in any manner whatever. For, as to the first branch of the case, if by the loss, or disorder, or decay of the parts in question, the movement of the watch were found in fact to be stopped, or disturbed, or retarded, no doubt would remain in our minds as to the utility or intention of these parts, although we should be unable to investigate the manner according to which, or the connexion by which, the ultimate effect depended upon their action or assistance; and the more complex is the machine, the more likely is this obscurity to arise. Then, as to the second thing supposed, namely, that there were parts which might be spared without prejudice to the movement of the watch, and that we had proved this by experiment, these superfluous parts, even if we were completely assured that they were such, would not vacate the reasoning which we had instituted concerning other parts. The indication of contrivance remained, with respect to them, nearly as it was before.

IV. Nor, fourthly, would any man in his senses think the existence of the watch, with its various machinery, accounted for, by being told that it was one out of many possible combinations of material forms; that whatever he had found in the place where he found the watch, must have contained some internal configuration or other; and that this configuration might be the structure now exhibited, viz., of the works of a watch, as well as a different structure.

V. Nor, fifthly, would it yield his inquiry more satisfaction, to be answered, that there existed in things a principle of order, which had disposed the parts of the watch into their present form and situation. He never knew a watch made by the principle of order; nor can he even form to himself an idea of what is meant by a principle of order, distinct from the intelligence of the watchmaker.

VI. Sixthly, he would be surprised to hear that the mechanism of the watch was no proof of contrivance, only a motive to induce the mind to think so:

VII. And not less surprised to be informed, that the watch in his hand was nothing more than the result of the laws of *metallic* nature. It is a perversion of language to assign any law as the efficient, operative cause of any thing. A law presupposes an agent; for it is only the mode according to which an agent proceeds: it implies a power; for it is the order according to which that power acts. Without this agent, without this power, which are both distinct from itself, the *law* does nothing, is nothing. The expression, "the law of metallic nature," may sound strange and harsh to a philosophic ear; but it seems quite as justifiable as some others which are more familiar to him, such as "the law of vegetable nature," "the law of animal nature," or, indeed, as "the law of nature" in general, when assigned as the cause of phenomena, in exclusion of agency and power, or when it is substituted into the place of these.*

* When philosophers and naturalists observe a certain succession in the phenomena of the universe, they consider the uniformity to exist through a *law of nature.* If they discover the order of events, or phenomena, they say they have discovered the law: for example, the law of affinities, of gravitation, &c. It is a loose expression; for to obey a law supposes an understanding and a will to comply. The phrase also implies that we know the nature of the governing power which is in operation, and in the present case both conditions are wanting.

The "law" is the mode in which the power acts, and the term should infer, not only an acquiescence in the existence of the power, but of Him who has bestowed the power and enforced the law.

The term "force" is generally used instead of power, when the intensities are measurable in their mechanical results.—Eng. Ed.

VIII. Neither, lastly, would our observer be driven out of his conclusion, or from his confidence in its truth, by being told that he knew nothing at all about the matter. He knows enough for his argument: he knows the utility of the end: he knows the subserviency and adaptation of the means to the end. These points being known, his ignorance of other points, his doubts concerning other points, affect not the certainty of his reasoning. The consciousness of knowing little need not beget a distrust of that which he does know.

CHAPTER II.

STATE OF THE ARGUMENT, CONTINUED.

SUPPOSE, in the next place, that the person who found the watch, should, after some time, discover that, in addition to all the properties which he had hitherto observed in it, it possessed the unexpected property of producing, in the course of its movement, another watch like itself, (the thing is conceivable;) that it contained within it a mechanism, a system of parts, a mould, for instance, or a complex adjustment of lathes, files, and other tools, evidently and separately calculated for this purpose; let us inquire what effect ought such a discovery to have upon his former conclusion.

I. The first effect would be to increase his admiration of the contrivance, and his conviction of the consummate skill of the contriver. Whether he regarded the object of the contrivance, the distinct apparatus, the intricate, yet in many parts intelligible mechanism by which it was carried on, he would perceive, in this new observation, nothing but an additional reason for doing what he had already done,—for referring the construction of the watch to design, and to supreme art. If that construction *without* this property, or, which is the same thing, before this

property had been noticed, proved intention and art to have been employed about it, still more strong would the proof appear, when he came to the knowledge of this further property, the crown and perfection of all the rest.

II. He would reflect, that, though the watch before him were, *in some sense*, the maker of the watch which was fabricated in the course of its movements, yet it was in a very different sense from that in which a carpenter, for instance, is the maker of a chair,—the author of its contrivance, the cause of the relation of its parts to their use. With respect to these, the first watch was no cause at all to the second; in no such sense as this was it the author of the constitution and order, either of the parts which the new watch contained, or of the parts by the aid and instrumentality of which it was produced. We might possibly say, but with great latitude of expression, that a stream of water ground corn; but no latitude of expression would allow us to say, no stretch of conjecture could lead us to think, that the stream of water built the mill, though it were too ancient for us to know who the builder was. What the stream of water does in the affair is neither more nor less than this; by the application of an unintelligent impulse to a mechanism previously arranged, arranged independently of it, and arranged by intelligence, an effect is produced, viz., the corn is ground. But the effect results from the arrangement. The force of the stream cannot be said to be the cause or author of the effect, still less of the arrangement. Understanding and plan in the formation of the mill were not the less necessary for any share which the water has in grinding the corn; yet is this share the same as that which the watch would have contributed to the production of the new watch, upon the supposition assumed in the last section. Therefore,

III. Though it be now no longer probable that the individual watch which our observer had found was made immediately by the hand of an artificer, yet doth not this alteration in anywise affect the inference, that an artificer had been originally employed and concerned in the pro-

duction. The argument from design remains as it was. Marks of design and contrivance are no more accounted for now than they were before. In the same thing, we may ask for the cause of different properties. We may ask for the cause of the color of a body, of its hardness, of its heat; and these causes may be all different. We are now asking for the cause of that subserviency to a use, that relation to an end, which we have remarked in the watch before us. No answer is given to this question, by telling us that a preceding watch produced it. There cannot be design without a designer; contrivance without a contriver; order without choice; arrangement, without any thing capable of arranging; subserviency and relation to a purpose, without that which could intend a purpose; means suitable to an end, and executing their office in accomplishing that end, without the end ever having been contemplated, or the means accommodated to it. Arrangement, disposition of parts, subserviency of means to an end, relation of instruments to a use, imply the presence of intelligence and mind. No one, therefore, can rationally believe, that the insensible, inanimate watch, from which the watch before us issued, was the proper cause of the mechanism we so much admire in it;—could be truly said to have constructed the instrument, disposed its parts, assigned their office, determined their order, action, and mutual dependency, combined their several motions into one result, and that also a result connected with the utilities of other beings. All these properties, therefore, are as much unaccounted for as they were before.

IV. Nor is any thing gained by running the difficulty further back, *i. e.*, by supposing the watch before us to have been produced from another watch, that from a former, and so on indefinitely. Our going back ever so far, brings us no nearer to the least degree of satisfaction upon the subject. Contrivance is still unaccounted for. We still want a contriver. A designing mind is neither supplied by this supposition, nor dispensed with. If the difficulty were diminished the further we went back, by going back indefinitely we might exhaust it. And this

is the only case to which this sort of reasoning applies. Where there is a tendency, or, as we increase the number of terms, a continual approach towards a limit, *there*, by supposing the number of terms to be what is called infinite, we may conceive the limit to be attained; but where there is no such tendency or approach, nothing is effected by lengthening the series. There is no difference, as to the point in question, (whatever there may be as to many points,) between one series and another; between a series which is finite, and a series which is infinite. A chain, composed of an infinite number of links, can no more support itself than a chain composed of a finite number of links. And of this we are assured, (though we never *can* have tried the experiment,) because, by increasing the number of links, from ten, for instance, to a hundred, from a hundred to a thousand, &c., we make not the smallest approach, we observe not the smallest tendency, towards self-support. There is no difference, in this respect, (yet there may be a great difference in several respects,) between a chain of a greater or less length, between one chain and another, between one that is finite and one that is infinite. This very much resembles the case before us. The machine which we are inspecting, demonstrates, by its construction, contrivance and design. Contrivance must have had a contriver; design, a designer; whether the machine immediately proceeded from another machine or not. That circumstance alters not the case. That other machine may, in like manner, have proceeded from a former machine: nor does that alter the case; the contrivance must have had a contriver. That former one from one preceding it: no alteration still; a contriver is still necessary. No tendency is perceived, no approach towards a diminution of this necessity. It is the same with any and every succession of these machines; a succession of ten, of a hundred, of a thousand; with one series, as with another; a series which is finite, as with a series which is infinite. In whatever other respects they may differ, in this they do not. In

all, equally, contrivance and design are unaccounted for.

The question is not, simply, How came the first watch into existence? which question, it may be pretended, is done away by supposing the series of watches thus produced from one another to have been infinite, and consequently to have had no such *first*, for which it was necessary to provide a cause. This, perhaps, would have been nearly the state of the question, if nothing had been before us but an unorganized, unmechanized substance, without mark or indication of contrivance. It might be difficult to show that such substance could not have existed from eternity, either in succession, (if it were possible, which I think it is not, for unorganized bodies to spring from one another,) or by individual perpetuity. But that is not the question now. To suppose it to be so, is to suppose that it made no difference whether he had found a watch or a stone. As it is, the metaphysics of that question have no place: for, in the watch which we are examining, are seen contrivance, design; an end, a purpose; means for the end, adaptation to the purpose. And the question, which irresistibly presses upon our thoughts, is, Whence this contrivance and design? The thing required, is, the intending mind, the adapted hand, the intelligence by which that hand was directed. This question, this demand, is not shaken off, by increasing a number or succession of substances, destitute of these properties; nor the more, by increasing that number to infinity. If it be said, that, upon the supposition of one watch being produced from another in the course of that other's movements, and by means of the mechanism within it, we have a cause for the watch in my hand, viz., the watch from which it proceeded,—I deny, that for the design, the contrivance, the suitableness of means to an end, the adaptation of instruments to a use, (all which we discover in the watch,) we have any cause whatever. It is in vain, therefore, to assign a series of such causes, or to allege that a series may be carried back to infinity; for I do not admit that we have yet any cause at all for the phenomena, still less in any series of causes either

finite or infinite. Here is contrivance, but no contriver; proofs of design, but no designer.

V. Our observer would further also reflect, that the maker of the watch before him was, in truth and reality, the maker of every watch produced from it: there being no difference (except that the latter manifests a more exquisite skill) between the making of another watch with his own hands, by the mediation of files, lathes, chisels, &c., and the disposing, fixing, and inserting of these instruments, or of others equivalent to them, in the body of the watch already made, in such a manner, as to form a new watch in the course of the movements which he had given to the old one. It is only working by one set of tools instead of another.

The conclusion, which the *first* examination of the watch, of its works, construction, and movement, suggested, was, that it must have had, for the cause and author of that construction, an artificer who understood its mechanism and designed its use. This conclusion is invincible. A *second* examination presents us with a new discovery. The watch is found, in the course of its movement, to produce another watch similar to itself; and not only so, but we perceive in it a system or organization, separately calculated for that purpose. What effect would this discovery have, or ought it to have, upon our former inference? What, as hath already been said, but to increase, beyond measure, our admiration of the skill which had been employed in the formation of such a machine? Or shall it, instead of this, all at once turn us round to an opposite conclusion, viz., that no art or skill whatever has been concerned in the business, although all other evidences of art and skill remain as they were, and this last and supreme piece of art be now added to the rest? Can this be maintained without absurdity? Yet this is atheism.*

* We must leave this logical and satisfactory argument untouched. In this chapter, our author is laying the foundation for a course of reasoning on the mechanism displayed in the animal body. The argument in favor of a creating and presiding Intelligence, may be drawn from the study of the laws of physical agency:—such as the properties of

[DISSERTATION ON CHAPTERS I. AND II., AND INTRODUCTORY TO THE MECHANISM OF THE FRAME.

Archdeacon Paley has, in these two introductory chapters, given us the advantage of simple, but forcible language, with extreme ingenuity, in illustration. But for his example, we should have felt some hesitation in making so close a comparison between design, as exhibited by the Creator in the animal structure, and the mere mechanism, the operose and imperfect contrivances of human art.

Certainly, there may be a comparison; for a superficial and rapid survey of the animal body may convey the notion of an apparatus of levers, pulleys, and ropes—which may be compared with the spring, barrel, and fusee, the wheels and pinions, of a watch. But if we study the texture of animal bodies more curiously, and especially if we compare animals with each other—for example, the simple structure of the lower creatures with the complicated structure of those higher in the scale of existence—we shall see, that in the lowest links of the chain, animals are so simple, that we should almost call them homogeneous; and yet in these we find life, sensibility, and motion. It is in the animals higher in the scale that we discover parts having distinct endowments, and exhibiting complex mechanical relations. The mechanical contrivances which are so obvious in man, for instance, are the provisions for the agency and dominion of an intellectual power over the materials around him.

We mark this early, because there are authors who,

heat, light, and sound; of gravitation, and chemical combination; the structure of the globe, the divisions of land and sea, the distribution of temperature; nay, the mind may rise to the contemplation of the sun and planets, their mutual dependence, and their revolutions; but, as affording proofs obvious not only to cultivated reason but to plain sense, almost to ignorance, there is nothing to be compared with that for which our author is preparing the reader in this chapter, the mechanism of the animal body, and the adaptations which affect the well-being of living creatures.—ENG. ED.

looking upon this complexity of mechanism, confound it with the presence of life itself, and think it a necessary adjunct,—nay, even that life proceeds from it: whereas, the mechanism which we have to examine, in the animal body, is formed with reference to the necessity of acting upon, or receiving impressions from, things external to the body,—a necessary condition of our state of existence in a material world.

Many have expressed their opinion very boldly on the necessary relation between organization and life, who have never extended their views to the system of nature. To place man, an intelligent and active being, in this world of matter, he must have properties bearing relation to that matter. The existence of matter implies an agency of certain forces;—the particles of bodies must suffer attraction and repulsion; and the bodies formed by the balance of these influences upon their atoms or particles must have weight or gravity, and possess mechanical properties. So must the living body, independently of its peculiar endowments, have similar composition and qualities, and have certain relations to the solids, fluids, gases, heat, light, electricity, or galvanism, which are around it. Without these, the intellectual principle could receive no impulse,—could have no agency and no relation to the material world. The whole body must gravitate or have weight; without which, it could neither stand securely, nor exert its powers on the bodies around it. But for this, muscular power itself, and all the appliances which are related to that power, would be useless. When, therefore, it is affirmed that organization or construction is necessary to life, we may at least pause in giving assent, under the certainty that we see another and a different reason for the construction of the body. Thus we perceive, that as the body must have weight to have power, so must it have mechanical contrivance, or arrangement of its parts. As it must have weight, so must it be sustained by a skeleton; and when we examine the bones, which give the body height and shape, we find each column (for in that sense a bone may be first taken) adjusted with the finest attention to

the perpendicular weight that it has to bear, as well as to the lateral thrusts to which it is subject in the motions of the body.

The bones also act as levers, on the most accurate mechanical principles. And whilst these bones are necessary to give firmness and strength to the frame, it is admirable to observe, that one bone never touches another; but a fine elastic material, the cartilage, intervenes betwixt their ends, the effect of which is to give a very considerable degree of elasticity to the whole frame. Without such elasticity, a jar would reach the more delicate organs, even in the very recesses of the body, at every violent motion; and, but for this provision, every joint would creak by the attrition of the surfaces of the bones. The bones are surrounded with the flesh or muscles. The muscle is a particular fibrous texture, which, alone, of all the materials constituting the frame, possesses the peculiar inherent power or endowment of contracting: it is this power which we are to understand, when professional men speak of irritability. The contraction of the muscle bears no proportion to the cause which brings it into operation, more than the touch of the spur upon the horse's side does as a mechanical impetus to the force with which the animal propels both himself and rider. Each muscle of the body,—and by common estimate there are hundreds,—is isolated; and no property of motion is propagated from one to another; they are distinct instruments of motion. The muscles surround the bones, and are so beautifully classed, that in every familiar motion of the limbs some hundreds of them are adjusted in their exact degree, to effect the simplest change in the position of the body.

Each fibre of a muscle, and a muscle may contain millions of fibres, is so attached to the tendon, that the whole power is concentrated there; and it is the tendons of the muscles which, like ropes, convey the force of the muscles to the bones. The bones are passive levers; the muscles are the active parts of the frame.

With all the seeming intricacy in the running and crossing of these tendons, they are adjusted accurately on

mechanical principles. Where it is necessary, they run in sheaths, or they receive new directions by lateral ligamentous attachments, or there are placed under them smooth and lubricated pulleys, over which they run; and where there is much friction, there is a provision equal in effect to the friction-wheel of machinery.

Thus the bones are levers, with their heads most curiously carved and articulated; and, joined to the intricate relations of the muscles and tendons, they present on the whole a piece of perfect mechanism.

It is with this texture,—the coarsest, roughest portion of the animal frame,—that our author is running a parallel when he compares it with the common mechanical contrivances of machinery. Whilst these grosser parts of the animal body exhibit a perfection in mechanical adaptation far greater than the utmost ingenuity of man can exhibit in his machinery, let the reader remember that they bear no comparison with the finer parts of the animal body; such, for example, as the structure of those nerves which convey the mandate of the will to the moving parts, or of the vessels which are conveying the blood in the circulation, and where the laws of hydraulics may be finely illustrated; or of those secreting glands where some will affirm the galvanic influence is in operation, with something finer than the apparatus of plates and troughs.

But were we to institute a comparison between the mechanical contrivances of man and these finer mechanisms in the animal frame, we must recollect that there are structures in the body much more admirable, as we shall have abundant opportunities of showing, as we proceed in the present volume. The organs of the senses, which are so many inlets for the qualities of surrounding matter to excite corresponding sensations and perceptions, will afford us delightful subjects of contemplation; and proofs more conclusive of design in the human body,—not only in regard to the system of that body itself, but as it forms a part of the system of the universe.

ON DESIGN, AS EXHIBITED IN THE MECHANICAL STRUCTURE OF ANIMAL BODIES.

In all animal bodies, besides those structures on which their economy and much of their vital functions depend, there is a firm texture necessary. Without this, the vegetable would have no characteristic form; and animals would want the protection necessary for their delicate organs, and could not move upon their extremities. We have to show with what admirable contrivance, in the different classes of organized beings, this firm fabric is reared, —sometimes, to protect the parts, as a shell, and sometimes, to give them form and motion, as in the skeleton.

In vegetables, as in animals, there is a certain firm material necessary to support the parts, which are the living, active organs of their system, and which are so beautiful and interesting. The ligneous or woody fibre is a minute, elastic, semi-opaque filament, which, closing in and adhering to other filaments of the same kind, forms the grain or solid part of the wood. The best demonstration of the office of the woody fibre is in the leaf. When the leaf of a plant is prepared by maceration and putrefaction, and the soft part washed away, there remains an elegant skeleton of wood, which retains the form of the leaf, and which is perfectly well suited to support its delicate organization. It is the same substance which, when accumulated and condensed, gives form and strength to the roots and branches of the oak; and these, though fantastic and irregular in their growth, preserve a mechanical principle of strength as obvious to the ship-builder, in the knees of timber, as in the delicate skeleton of the leaf. Lord Bacon speaks of "knee-timber, that is good for ships that are to be tossed." The woody fibre, though not directly engaged in the living functions of the tree, is yet essential for extending the branches and leaves to the influence of the atmosphere, and by its elasticity under the pressure of the wind, giving what is equivalent to exercise for the motion of the sap. A tree opposed to winds and to a severe climate is dense in its grain, and the wood is

preferred by the workman to that which is the growth of a milder climate.

We cannot miss seeing the analogy of the woody fibre with the bones of animals. Bones are firm, to sustain the animal's weight, and to give it form. They are jointed, and move under the action of muscles; and this exercise promotes the activity of the living parts, and is necessary to health. But let us first observe the structure of some of the lower animals. It will be agreeable to find the hard material, though always appropriate and perfect, becoming more and more mechanical and complex in its construction, from the lithophytes, testacea, crustacea, reptiles, fishes, mammalia, up to man.

The texture of a sponge, its form and elasticity, depend upon a membranous and horny substance, to which both siliceous and calcareous spiculæ are added.

Carbonate of lime is the hardening material of shell, united to a membranous or cartilaginous animal matter. Our authoı describes the slime of a snail hardening into shell by the influence of the atmosphere; but this is a very imperfect, and indeed erroneous, view of the matter. The shell of the oyster, and even the pearl, consists of concentric layers of membrane and carbonate of lime; and it is their lamellated arrangement which causes the beautiful iridescence in the polished surface of those shells.* In the rough outer surface of an oyster-shell, we shall see the marks of the successive layers. We have to understand, that that which now forms the centre and utmost convexity of the shell was, at an earlier stage, sufficient to cover the whole animal. But as the oyster grows, it throws out from its surface a new secretion, composed of animal matter and carbonate of lime, which is attached to the shell already formed, and projects further at its edges. Thus the animal is not only protected by this covering, but, as it grows, the shell is made thicker and stronger by successive layers.

The reader will not be unwilling that we should stop

* See the discoveries of Sir David Brewster on this subject, Phil. Trans. 1814, p. 397.

here, to show, that, rudely composed as this covering of the oyster seems to be, it not only answers the purpose of protecting the animal, but is shaped with as curious a destination to the vital functions of respiration and obtaining food as any thing we can survey in the higher animals. We cannot walk the streets, without noticing, that, in the fish-shops, the oysters are laid with their flat sides uppermost; they would die, were it otherwise. The animal breathes and feeds by opening its shell, and thereby receiving a new portion of water into the concavity of its under-shell; and if it did not thus open its shell, the water could neither be propelled through its bronchiæ or respiratory apparatus, nor sifted for its food. It is in this manner that they lie in their native beds: were they on their flat surface, no food could be gathered, as it were, in their cup; and, if exposed by the retreating tide, the opening of the shell would allow the water to escape, and leave them dry,—thus depriving them of respiration as well as food.*

We perceive, then, that the form of the oyster-shell, rude as it seems, is not a thing of chance. Since the shell is a cast of the body of the animal, the peculiar shape must have been given to the soft parts, in anticipation of that of the shell,—an instance of prospective contrivance.

That the general conformation of the shell should have relation to what we may term its function, will be less surprising when we find a minute mechanical intention in each layer of that shell. We should be inclined to say that the earthy matter of the shell crystallizes, were it not that the striated or fibrous appearance differs in the direction of the fibres in each successive stratum,—each layer having the striæ composing it parallel to one another, but directed obliquely to those of the layer previously formed, and the whole exhibiting a strong texture arranged upon wellknown mechanical principles.

* In confirmation of these remarks, the geologist, when he sees those shells in beds of diluvium, can determine whether the oysters were overwhelmed in their native beds, or were rolled away and scattered as shells merely.

Shell is not alive, as true bone is. If the shell of any of the testacea be broken, the surface of the animal secretes a new shell; not, however, by the concretion of mucus, but by the regular secretion of a substance combined of earthy and gelatinous matter. Delicate experiments have been made by steeping shells in diluted nitric acid, by which it is shown that the carbonate of lime is the earthy material of shells; and that, when that earth is dissolved in the acid, a gelatinous substance of the form of the shell remains.

Crustaceous animals, such as the lobster and crab, have their shell formed of the same substances as the testacea, but with the addition of phosphate of lime to the carbonate of lime. A question may arise, How do these animals grow? It is said, that they cast their shells and remain retired until a new shell is secreted; and Réaumur has given a very particular account of the process of separation in the cray-fish. Naturalists have not found these cast-off shells. If they be not cast, the animals must, at a particular season, have their shells so softened as to permit sudden expansion of their bodies within; yet it would be difficult to say by what internal means this shell could be thus softened and made pliant. We presume, the reason that the shells of the crustacea are not found in our museums, is, because they are not thrown off at once, but that the portions are detached in succession. In these crustacea, we find an approximation to bone, inasmuch as the shell is articulated, and has certain processes directed inwards to which the muscles are attached.

The hardening material of bone is the phosphate of lime; and this earthy substance is not merely united with cartilage or gelatinous matter, but membranes and vessels enter into the composition of bone. Bone is not excreted, or thrown out of the system of the animal body, but, on the contrary, it participates in those laws that govern living matter. It is continually undergoing the changes of deposition and absorption, under the influence of blood-vessels and absorbing vessels; by which means it grows with the growth of the soft parts.

In fishes, which live in an element that supports the weight, the bones have a very large proportion of elastic cartilage in their composition, and some have so little of the phosphate of lime in their bones as to be denominated cartilaginous fishes. Indeed, in the higher classes of animals which live upon land, there is in the different bones a finely-appropriated union of earth, cartilage, and fibre, to give them the due proportion of resistance, elasticity, and toughness. Not only is the bone of each class of animal peculiar in the proportion of the ingredients, but each bone of the skeleton, as of man, has a due proportion of earth, and cartilage, and fibre to suit its office. The temporal bone, in which the ear is situated, is as dense as marble, (it is called *os petrosum*,) and of course is suited to propagate the vibration of sound : the heel-bone, or the projection of the elbow, on which the powerful muscles pull, is, on the other hand, fibrous, as if partaking of the nature of a tendon or rope ; whilst the columnar bones, which support the weight, have an intermediate degree of density, and an admirable form, as we shall see presently.

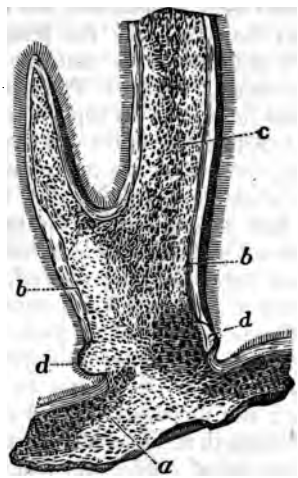
Let us consider the structure, growth, and decay of the deer's horns, as an example of the most rapid growth of bone, and a curious instance of its appropriation to a particular purpose. And, first, why should these antlers be deciduous, falling at an appointed season? The breeder of domestic cattle and horses endeavors to propagate the favorite qualities of fleece or carcass, of speed or power, by crossing. Nature accomplishes her purpose, by giving to the strongest.

The antlers of the stag which is in maturity and vigorous health, grow with the greatest spread of palms and crotches : with the growth of the horn, there is increase of strength in the neck and shoulder.* We cannot be surprised, then, that in contention with his rivals, he that carries the largest antlers should obtain supremacy over the herd. After the season, his antlers fall ; and we then find the stag feeding with the other males, which before

* The carotid artery, which nourishes the head, increases rapidly in size during the growth of the antlers.

he had driven off. Be this, however, as it may, the growth and fall of the horn is a remarkable phenomenon, and deserving further consideration.

The horn of the deer is bone, and is formed as an internal part, that is to say, it is covered during its growth. It grows from the outer table of the skull, *a*; but there extends, at the same time, from the integuments of the head, a soft, vascular covering, *b*, like velvet; so that,



[Section of the root of a deer's horn.]

during the whole period of its growth, the horn, *c*, has around it a tender, soft covering, full of vessels, and which is necessary to its growth and support. But when the horn has acquired its full form and strength, this velvet covering is destroyed by a very curious process. At the root of the horn, near the skull, a circlet of tubercles, *d*, called the burr or pearl, is found: the principal vessels run between these tubercles, and, as the tubercles grow, they close in upon the ascending blood-vessels, compress them, and prevent their conveying blood to

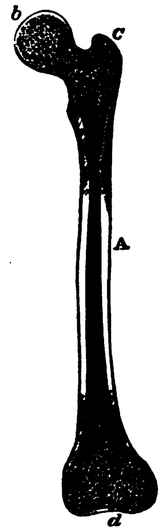
the horn: then the membrane, which was vascular, becomes insensible and dead, and in time is rubbed off.

In old treatises on hunting, the separation of the outer cuticle, or velvet, is called fraying; and the huntsman, in leading on his hounds upon a hart of many "tines," judges of his size and strength by the fraying-post—the height of the tree against which he has been butting and rubbing his horns to separate the outer covering. The horns, when the velvet is detached, are now perfect. It is after this that the stag seeks the female in the depth of the forest; and now it is that, in encountering his rivals, fierce contests ensue. They dart against each other with great fury, take no repose, and in a very few weeks become quite exhausted. In the museum of the College of Surgeons, there are two superb sets of antlers entangled and wedged together: they belonged to two males, which had struck so fiercely against each other that they could not withdraw their horns, and being thus strangely locked together, they starved, and were found dead. The stag is a very different animal, in regard to strength, at different seasons of the year. He feeds, too, on different herbage, sometimes preferring the broom and heath; at another season he resorts to copses, springs, and corn-fields; and these correspond with his different condition as to strength and fatness, and with his passions. It is after the period of contention that the stag is once more found in the copses and underwood, feeding peacefully with his former rivals. And now the process of absorption takes place at the root of the horns, and they are shed: sometimes one is carried a considerable time after the other is fallen; and it is observed that the oldest and strongest harts shed their antlers the soonest. The remarkable circumstance is, that such is the provision, through the absorption at the root of the horn, that a slight shock will now detach that which bore the united force of the two combatants before. The fallow-deer have the same habits and passions; but they will contend in herds for favorite pasture-grounds, and divide into parties under the oldest and strongest of the herd. Who

can doubt that the antlers are for a temporary purpose, since, for the greater part of the year, they are either wanting, or in a tender state of growth. Nature bestows them, only as arms for the combat which is to decide for the strongest, and give a sire to the herd.

We shall now advert to the forms of the bones of the greater animals, and to those of man. That the bones which form the interior of animal bodies should have the most perfect shape, combining strength and lightness, ought not to surprise us, when we find this in the lowest vegetable production.

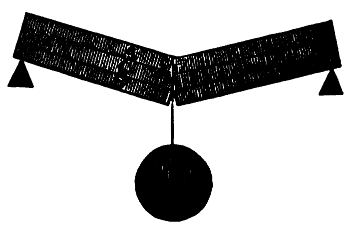
A reed, or a quill, or a bone, may be taken, to prove, that, in Nature's works, strength is given with the least possible expense of materials. The long bones of animals are for the most part hollow cylinders, filled up with



[A section of the femur, or thigh-bone, to show the hollow of its shaft, and the cancellated structure of its upper and lower ends ; *b*, the head, by which it is articulated to the pelvis ; *c*, the great trochanter ; *d*, the surface by which it is articulated to the leg.]

the lightest substance, marrow; and in birds the object is attained by means (if we may be permitted to say so) still more artificial. Every one must have observed, that the breast-bone of a fowl extends along the whole body, and that the body is very large compared with the weight: this is for the purpose of rendering the creature specifically lighter and more buoyant in the air; and that it may have a surface for the attachment of muscles equal to the exertion of raising it on the wing. This combination of lightness with increase of volume is gained by air-cells extending through the body, and communicating by tubes between the lungs and cavities of the bones. By these means, the bones, although large and strong, to withstand the operation of powerful muscles upon them, are much lighter than those of quadrupeds.

The long bones of the human body, being hollow tubes, are called cylindrical, though they are not accurately so, the reason of which, we shall presently explain; and we shall, at the same time, show that their irregularities are not accidental, as some have imagined. But let us first demonstrate the advantage, which, in the structure of the bones, is derived from the cylindrical form, or a form approaching that of a cylinder. If a piece of timber supported on two points, thus—

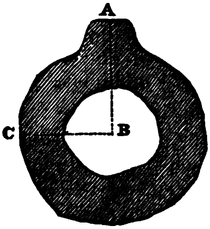


bear a weight upon it, it sustains this weight by different qualities in its different parts. For example, divide it into three equal parts, (A, B, C:) the upper part, A, supports the weight by its solidity and resistance to compression; the lowest part, B, on the other hand, resists by its toughness or adhesive quality. Between the portions acting in so different a manner, there is an interme-

diate neutral or central part, C, that may be taken away without materially weakening the beam, which shows that a hollow cylinder is the form of strength. We may observe a further illustration of this, when a tree is blown down and broken at the stem: to the windward, the broken part gapes; it has been torn asunder like the snapping of a rope: to the leeward side of the tree, the fibres of the stem are crushed into one another and splintered; while the central part is bent. This, we presume, must always be the case, more or less. We may observe, too, why the arch is the form of strength. If this transverse piece of timber were in the form of an arch, and supported at the extremities, then its whole thickness, its centre, as well as the upper and lower parts, would support weight by resisting compression.

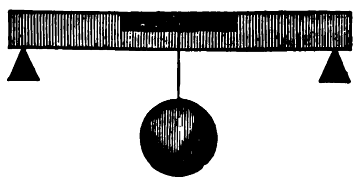
But the demonstration may be carried much further, to show the form of strength in the bone. If the part of the cylinder which bears the pressure, be made more dense, the power of resistance will be much increased; whereas, if a ligamentous covering be added on the other side, it will strengthen the part which resists extension; and we observe a provision of this kind in the tough ligaments which run along the vertebræ of the back.

When we see the bone cut across, we are forced to acknowledge that it is formed on the principle of the cylinder; that is, that the material is removed from the centre, and accumulated on the circumference, thus—



We find a spine or ridge, A, running along the bone, B C, which, when divided by the saw in a transverse direction, exhibits the irregularity, whereof A is the section.

The section of this spine shows a surface as dense as ivory; that part is, therefore, much more capable of resisting compression than the other part of the cylinder, which is common bone. This declares what the spine is, and the anatomists must be wrong, who imagine that the bone is moulded by the action of the muscle, or that the spine is a mere ridge, arising by accident among the muscles. It is, on the contrary, a strengthening of the bone in the direction on which the weight bears. If we resume the experiment with the piece of timber, we shall learn why the spine is harder than the rest of the bone. If a portion of the upper part of the timber be cut away, and a harder wood inserted in its place, the insertion of the harder portion of wood increases this property of resistance. With this fact before us, we may return to the



examination of the spine of bone. We see that it is calculated to resist pressure, first, because it is further removed from the centre of the cylinder, and, secondly, because it is more dense, to resist compression, than the other parts of the circumference of the bone.

This explanation of the use of a spine upon a bone, gives a new interest to osteology. The anatomist ought to deduce from the form of the spine the motions of the limb, the forces bearing upon the bone, and the nature and the common place of fracture; while, to the general inquirer, an agreeable process of reasoning is introduced in that department, which is altogether without interest when the "*irregularities*" of the bone are spoken of, as if they were the accidental consequences of the pressure of the flesh upon it.

Although treating of the purely mechanical principle, *it is, perhaps*, not far removed from our proper object to

remark that a person of feeble texture and indolent habits has the bone smooth, thin, and light; but that Nature, solicitous for our safety, in a manner which we could not anticipate, combines with the powerful muscular frame a dense and perfect texture of bone, where every spine and tubercle is completely developed. And thus the inert and mechanical provisions of the bone always bear relation to the living muscular power of the limb, and exercise is as necessary to the perfect constitution and form of a bone as it is to the increase of the muscular power. Jockeys speak correctly enough when they use the term "*blood and bone*," as distinguishing the breed or genealogy of horses; for blood is an allowable term for the race, and bone is so far significant, that the bone of a running horse is remarkably compact compared with the bone of a draught horse. The reader can easily understand, that, in the gallop, the horse must come on his fore-legs with a shock proportioned to the span; and that in the horse, as in man, the greater the muscular power, the denser and stronger is the bone. The bone not being as a mere pillar, intended to bear a perpendicular weight, we ought not to expect uniformity in its shape. Each bone, according to its place, bears up against the varying forces that are applied to it. Consider two men wrestling together, and then think how various the direction of the resistances must be: now, they are pulling, and the bones are like ropes; or, again, they are writhing and twisting, and the bones bear a force like the axletree between two wheels; or, they are like a pillar under a great weight; or, those bones are acting as levers. We see, therefore, why, to withstand these different shocks, a bone should consist, as we have stated, of three parts, the *earth* of bone, (sub-phosphate of lime,) to give it firmness; *fibres*, to give it toughness; and *cartilage*, to give it elasticity.

The great functions, by which animals live and breathe and are nourished, are the same though the whole chain, from the simplest polypus or mass of jelly that floats in the sea, to the largest and most complex of all terrestrial creatures. The appetite for food, and the powers of assimila-

tion, circulation, aeration, secretion, are the same functions in all living creatures, only modified by their size or condition. When we consider the astonishing variety in the shape of animated beings, we are apt to forget the necessity of apportioning their size and strength, not only to the vegetable productions and to the materials found on the surface of the earth, but to the magnitude of the globe,—to the "great motions that are passing in the heavens." On that plan of living structure which pervades all the varieties of animals in which bones afford resistance and muscles activity, there must be a limit to stature. The resisting parts of the smaller animals, which have an external covering instead of bones, have comparatively much less material in them than the larger. Accordingly, philosophers have contrasted the power of the flea with that of the horse, deciding greatly in favor of the former. The rationale of this, is not quite apparent, at first; but a little consideration will convince us, that the resisting material being exterior to the animal's body, and consequently removed from the centre, it must possess more power against transverse fracture, as well as bestow a mechanical advantage for the action of the muscles. But this is not all: any degree of density and strength may be given to it, from its being a mere secretion, and being unorganized. We may compare, however, the bones of man with those of the elephant, or other huge animals.* Now it would seem, that the material of bone (which we must recollect is porous, since it constitutes a living part, and is nourished by blood-vessels) could not, by any variety of conformation, bear up a greater mass than that of the elephant. On examining the bones of these immense animals, including the megatherium and rhinoceros, they are dense and strong, and clumsy, as we would term it; their spines and processes are large, and their cavities filled up: all which indicates, that to support a larger animal on extremities, some other material than the vascular bone would be required. Those immense bones that are found in digging the earth, and which, in ignorant ages, have given rise to strange fan-

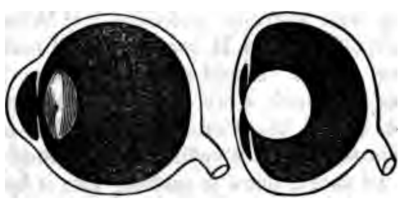
* Vol. i. p. 360.

cies, are the bones of animals inhabiting the water,—whales or reptiles,—whose bulk was extended in the water, or that crawled on their bellies, and they could never have given support sufficient to have raised their enormous weight on extremities.—SIR CHARLES BELL.]

CHAPTER III.

APPLICATION OF THE ARGUMENT.

THIS is atheism: for every indication of contrivance, every manifestation of design, which existed in the watch, exists in the works of Nature; with the difference, on the side of Nature, of being greater and more, and that in a degree which exceeds all computation. I mean, that the contrivances of Nature surpass the contrivances of art, in the complexity, subtilty, and curiosity of the mechanism; and still more, if possible, do they go beyond them in number and variety; yet, in a multitude of cases, are not less evidently mechanical, not less evidently contrivances, not less evidently accommodated to their end, or suited to their office, than are the most perfect productions of human ingenuity.



I know no better method of introducing so large a subject, than that of comparing a single thing with a single thing: an eye, for example, with a telescope. As far as the examination of the instrument goes, there is precisely the same proof that the eye was made for vision, as there is that the telescope was made for assisting it. They are made upon the same principles; both

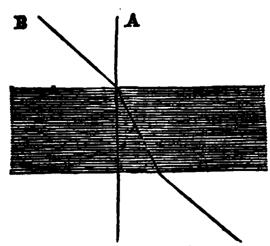
being adjusted to the laws by which the transmission and refraction of rays of light are regulated. I speak not of the origin of the laws themselves; but such laws being fixed, the construction in both cases is adapted to them. For instance; these laws require, in order to produce the same effect, that the rays of light, in passing from water into the eye, should be refracted by a more convex surface than when it passes out of air into the eye. Accordingly, we find that the eye of a fish, in that part of it called the crystalline lens, is much rounder than the eye of terrestrial animals. What plainer manifestation of design can there be than this difference? What could a mathematical instrument-maker have done, more, to show his knowledge of his principle, his application of that knowledge, his suiting of his means to his end; I will not say, to display the compass, or excellence of his skill and art, for in these, all comparison is indecorous, but to testify counsel, choice, consideration, purpose?

[ON THE RAYS OF LIGHT, THEIR REFRACTION AND REFLECTION.

The nature of light has ever been a subject of controversy. It was Newton's explanation, that luminous objects give out particles of inconceivable minuteness, and moving with extreme velocity. "What mere assertion," says Sir John Herschel, "will make any man believe that, in one second of time, in one beat of the pendulum of the clock, a ray of light travels over 192,000 miles; and would therefore perform the tour of the world in less time than a swift runner would make one stride?" In short, there is nothing like it but the influence of attraction; which is so instantaneous as to admit of no calculation of time at all.

A different theory from that of Newton was suggested by Huygens, who supposed a highly-elastic fluid to fill all space, and which, when moved, produced the effects ascribed to light. Instead of minute particles diverging from the luminous body, he substituted waves or

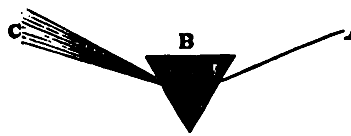
vibrations, propagated through this elastic ether. The late Dr. Young, and some continental philosophers, more recently, took up this hypothesis, and supported it by ingenious experiments. But, notwithstanding that it is the favorite theory of the day, difficulties appear still to encumber it. The theory of undulations, implies the advance and recoil of the elastic medium, and that gives the idea of retardation. The supposition of light being the effect of the motion of an ether, does not fall in with our conceptions of the manner in which it enters into the composition of bodies, or influences chemical combinations, or affects the living powers of animals and vegetables. The merits of the two theories, however, need not be discussed here. It will be sufficient for our purpose to represent a beam of light by a line drawn with the pen, and to enter on the explanation of a few of the laws which influence it in passing through transparent media.



When the ray of light, as A, passes perpendicularly from a rarer, into a denser medium, as from air into water, it suffers no change in its direction ; but when it passes obliquely, as B, it takes a new direction towards the perpendicular, making a sudden angle, as if broken,—and this is refraction. Two circumstances, therefore, influence the ray of light ;—the angle at which it falls, and the density of the body into which it passes. When the ray B passes from the denser medium into the rarer, it is again refracted, but away from the perpendicular, and takes its original course, provided the surface at which it goes out is parallel to the surface at which it entered.

When a ray strikes upon a body that is not transparent, or only imperfectly so, it is in part reflected, that is, struck off again, bent back or reflected, and enters the eye, conveying to us the impression of the form and color of that object.

But the expression which we have used requires explanation; for how is it that the reflected rays should convey the idea of color?

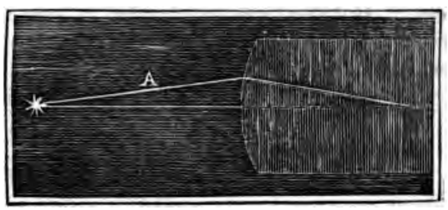


The prism is a piece of glass so formed that the rays must fall obliquely on one or both of the surfaces, and suffer refraction. Thus, the ray A, striking into the prism B, is refracted; but all its parts are not equally refracted, and as the light consists of parts differing in colors, and which are differently refracted, it is divided or dissected into several colors C, called the prismatic colors. The spectrum, as it is termed, thus formed, consists of seven colors; that which is least refracted being red, and in succession, orange, yellow, green, blue, indigo, and violet. If these rays be recompounded, by passing through a convex lens, which, owing to the obliquity with which they fall, draws them to a point, the focus of the light will be again colorless. Some modern philosophers have reduced these prismatic colors of Newton to three primary colors, red, yellow, and blue; contriving, by the super-position of these, to produce the seven tints; while others have, on considerations not easy to be disproved, held that there is not any definite number of colors, but a gradation of tints from the extreme red to the extreme violet.

We may now understand the reason of the color of objects. When light strikes upon a body, even upon the most transparent, part penetrates, part is reflected, and some part is lost. A dye is a disposition given to the surface of cloth to repel some of the rays of light more

than the others ; and the color will be according to the ray, or the combination of rays, thus cast back and sent into the eye.

And here, it is natural to reflect on the variety and beauty every where bestowed through this property of the beam of light. What a dulness would have pervaded the surface of the earth if there had been only a white light ! The beauties of the garden and of the landscape would have been lost to us. How is the beauty of the latter enhanced by the almost infinite variety of color, yet still within that range which is agreeable and soothing to the eye, as well as consonant to our feelings ! The human countenance, too, although capable of exciting our warmest sympathies by form and motion alone, has that beauty perfected by color, varying under the influence of emotion.



It remains, in order that we may apply these facts to the explanation of the structure of the eye, to show how the rays proceeding from a body and falling upon a convex glass suffer refraction. The ray that strikes upon the centre, being perpendicular to the glass, passes on undeviatingly. But each ray as it strikes a point removed from the centre, must impinge with more obliquity, in consequence of the curved surface ; and as the refraction of all the rays will be in proportion to the obliquity of their incidence, they will converge towards the central direct ray. Thus, A, as it passes through the glass, suffers refraction towards the perpendicular line, in proportion as it deviated from it, on passing out of the air into the glass. These few simple statements may suffice for understanding the comparison which we are now to

make between the eye and optical instruments.—Sir Charles Bell.]

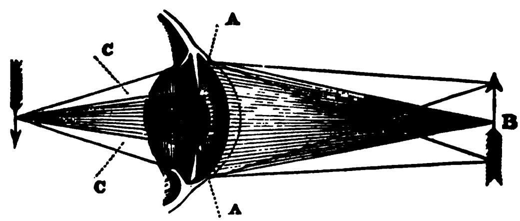
To some it may appear a difference sufficient to destroy all similitude between the eye and the telescope, that the one is a perceiving organ, the other an unperceiving instrument. The fact is, that they are both instruments. And, as to the mechanism, at least as to mechanism being employed, and even as to the kind of it, this circumstance varies not the analogy at all. For observe what the constitution of the eye is. It is necessary, in order to produce distinct vision, that an image or picture of the object be formed at the bottom of the eye. Whence this necessity arises, or how the picture is connected with the sensation, or contributes to it, it may be difficult, nay, we will confess, if you please, impossible for us to search out. But the present question is not concerned in the inquiry. It may be true, that, in this, and in other instances, we trace mechanical contrivance a certain way; and that then we come to something which is not mechanical, or which is inscrutable. But this affects not the certainty of our investigation, as far as we have gone. The difference between an animal and an automatic statue consists in this,—that, in the animal, we trace the mechanism to a certain point, and then we are stopped; either the mechanism being too subtile for our discernment, or something else, besides the known laws of mechanism, taking place; whereas, in the automaton, for the comparatively few motions of which it is capable, we trace the mechanism throughout. But, up to the limit, the reasoning is as clear and certain in the one case as in the other. In the example before us, it is a matter of certainty, because it is a matter which experience and observation demonstrate, that the formation of an image at the bottom of the eye is necessary to perfect vision. The image itself can be shown. Whatever affects the distinctness of the image, affects the distinctness of the vision. The formation, then, of such an image, being necessary (no matter how) to the sense of sight, and to the exercise of that sense, the apparatus, by which it is form-

ed, is constructed and put together, not only with infinitely more art, but upon the selfsame principles of art, as in the telescope or the camera-obscura. The perception arising from the image may be laid out of the question; for the production of the image, these are instruments of the same kind. The end is the same; the means are the same. The purpose in both is alike; the contrivance for accomplishing that purpose is in both alike. The lenses of the telescope, and the humors of the eye, bear a complete resemblance to one another, in their figure, their position, and in their power over the rays of light, viz., in bringing each pencil to a point at the right distance from the lens; namely, in the eye, at the exact place where the membrane is spread to receive it. How is it possible, under circumstances of such close affinity, and under the operation of equal evidence, to exclude contrivance from the one; yet to acknowledge the proof of contrivance having been employed, as the plainest and clearest of all propositions, in the other?

The resemblance between the two cases is still more accurate, and obtains in more points than we have yet represented, or than we are, on the first view of the subject, aware of. In dioptric telescopes there is an imperfection of this nature. Pencils of light, in passing through glass lenses, are separated into different colors, thereby tinging the object, especially the edges of it, as if it were viewed through a prism. To correct this inconvenience, had been long a desideratum in the art. At last it came into the mind of a sagacious optician, to inquire how this matter was managed in the eye; in which there was exactly the same difficulty to contend with as in the telescope. His observation taught him, that, in the eye, the evil was cured by combining lenses composed of different substances, *i. e.*, of substances which possessed different refracting powers. Our artist borrowed thence his hint; and produced a correction of the defect, by imitating, in glasses made from different materials, the effect of the different humors through which the rays of light pass before they reach the bottom of the eye. Could this be in *the eye* without purpose, which suggested to

the optician the only effectual means of attaining that purpose?

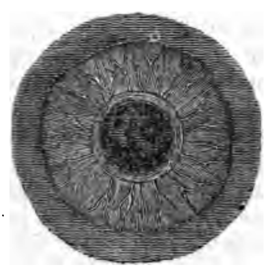
But further; there are other points, not so much perhaps of strict resemblance between the two, as of superiority of the eye over the telescope; yet of a superiority which, being founded in the laws that regulate both, may furnish topics of fair and just comparison. Two things were wanted to the eye, which were not wanted (at least in the same degree) to the telescope; and these were the adaptation of the organ, first, to different degrees of light; and secondly, to the vast diversity of distance at which objects are viewed by the naked eye, viz., from a few inches to as many miles. These difficulties present not themselves to the maker of the telescope. He wants all the light he can get; and he never directs his instrument to objects near at hand. In the eye, both these cases were to be provided for; and for the purpose of providing for them, a subtile and appropriate mechanism is introduced.



[The next figure represents a section of the anterior part of the human eye:—A, A, the iris; B, the object, from which the rays strike off in all directions: a pencil of these enters at the pupil; a portion is intercepted by the iris, A, A. The pencil which enters the eye, passing through the lens, converges to form the image. But the spaces, C, C, are deprived of rays by the intervention of the iris, A, A. Yet this in no measure affects the size of the image, but only diminishes the intensity of its illumination. By the contraction of the iris, and consequent enlargement of the pupil, a larger pencil of rays is admitted. It is remarkable that the image formed on the retina must *always be* inverted, and yet such is the power of habit and

experience, derived from touching objects, that we see things as they are in reality, and not as they are painted in our eyes ; experience thus correcting the errors of sense. It is in the same way that we see single, though we have an image made in each eye. But if we change the ordinary position of our eye, the habit is broken, and we see double.]

I. In order to exclude excess of light, when it is excessive, and to render objects visible under obscurer degrees of it, when no more can be had, the hole or aperture in the eye, through which the light enters, is so formed as to contract or dilate itself for the purpose of admitting a greater or less number of rays at the same time. The chamber of the eye is a camera-obscura, which, when the light is too small, can enlarge its opening ; when too strong, can again contract it ; and that without any other assistance than that of its own exquisite machinery. It is further, also, in the human subject, to be observed, that this hole in the eye, which we call the pupil, under all its different dimensions, retains its exact circular shape. This is a structure extremely artificial. Let an artist only try to execute the same ; he will find that his threads and strings must be disposed with great consideration and contrivance, to make a circle which shall continually change its diameter yet preserve its form. This is done in the eye by an application of fibres, *i. e.*,



[This figure represents the iris, separated from the eye and laid out flat. We perceive the straight fibres *passing towards the inner* margin, and the circular fibres *running round the* margin.]

of strings similar, in their position and action, to what an artist would and must employ, if he had the same piece of workmanship to perform.

II. The second difficulty which has been stated was the suiting of the same organ to the perception of objects that lie near at hand, within a few inches, we will suppose, of the eye, and of objects which are placed at a considerable distance from it, that, for example, of as many furlongs; (I speak in both cases of the distance at which distinct vision can be exercised.) Now this, according to the principles of optics, that is, according to the laws by which the transmission of light is regulated, (and these laws are fixed,) could not be done without the organ itself undergoing an alteration, and receiving an adjustment, that might correspond with the exigency of the case, that is to say, with the different inclination to one another under which the rays of light reached it. Rays issuing from points placed at a small distance from the eye, and which consequently must enter the eye in a spreading or diverging order, cannot, by the same optical instrument in the same state, be brought to a point, *i. e.*, be made to form an image, in the same place with rays proceeding from objects situated at a much greater distance, and which rays arrive at the eye in directions nearly (and physically speaking) parallel. It requires a rounder lens to do it. The point of concourse behind the lens must fall critically upon the retina, or the vision is confused; yet, other things remaining the same, this point, by the immutable properties of light, is carried further back when the rays proceed from a near object than when they are sent from one that is remote. A person who was using an optical instrument would manage this matter by changing, as the occasion required, his lens or his telescope, or by adjusting the distance of his glasses with his hand or his screw: but how is this to be managed in the eye? What the alteration was, or in what part of the eye it took place, or by what means it was effected, (for if the known laws which govern the refraction of light be maintained, some alteration in the state of the organ there must be,) had long formed a subject of inquiry and conjecture. The

change, though sufficient for the purpose, is so minute as to elude ordinary observation. Some very late discoveries, deduced from a laborious and most accurate inspection of the structure and operation of the organ, seem at length to have ascertained the mechanical alteration which the parts of the eye undergo. It is found, that by the action of certain muscles, called the straight muscles, and which action is the most advantageous that could be imagined for the purpose, it is found, I say, that whenever the eye is directed to a near object, three changes are produced in it at the same time, all severally contributing to the adjustment required. The cornea, or outermost coat of the eye, is rendered more round and prominent; the crystalline lens underneath is pushed forward; and the axis of vision, as the depth of the eye is called, is elongated. These changes in the eye vary its power over the rays of light in such a manner and degree as to produce exactly the effect which is wanted, viz., the formation of an image *upon the retina*, whether the rays come to the eye in a state of divergency, which is the case when the object is near to the eye, or come parallel to one another, which is the case when the object is placed at a distance. Can any thing be more decisive of contrivance than this is? The most secret laws of optics must have been known to the author of a structure endowed with such a capacity of change. It is as though an optician, when he had a nearer object to view, should rectify his instrument by putting in another glass, at the same time drawing out also his tube to a different length.[5]

[5] This is a subject over which there is still great obscurity, and on which adverse experiments and opinions are recorded. However difficult it may be to account for the mode of adjustment, yet the property is not denied, and therefore the argument in the text remains. That there is something in the sensibility of the nerve, and in the power of attention, there seems no doubt. Birds of prey, it has been noticed, possess a power of vision of which we can hardly form a conception. Where it is the object to snare the falcon, a pigeon is tied, in an exposed situation, with a cord so attached that a person concealed can flutter the bird, or make it extend its wings; and although no bird of prey be visible in the whole sky, presently the hawk will be seen descending to pounce upon the pigeon. The endowment of the bird's eye must be different from ours, else the *bird of prey* could not see the most minute object when

[THE EYE COMPARED WITH OPTICAL INSTRUMENTS.

We have elsewhere expressed our surprise that the structure of an animal body should so seldom be taken as a model. In the history of invention, it appears quite extraordinary, that the telescope and the microscope should be modern, when, as it should seem, the fine transparent convexity of the eye might have given rise to imitation, as soon as man learned to give shape to natural or artificial glass. It reminds us of the observation of Locke, in speaking of a discovery, that it proved the world to be of no great antiquity. Yet we must estimate the invention of the telescope and microscope, as by far the most important in their consequences of either ancient or modern discoveries. The first opens to us an unlimited expanse, not only of new worlds, but systems of worlds, and new laws evinced in the forces which propel and attract these; since in the heavenly bodies we find no material contact, nor pressure, nor impulse, nor transfer of power, nor effect of heat, nor expansion of gases,—nothing, in short, which can be illustrated by mechanism. By the microscope, we contemplate the minute structure of animals and things, but for its aid, invisible; the balance of the cohesive and repulsive forces as they order the changes in the material of the world, and in that of our own frames. Yet these instruments are not in contrast with the eye: but through the comparison of them we discover the wonderful adaptations of that organ; of which it has long ago been said, that it can, at one time, extend our contemplations to the heavenly bodies and their revolutions, and at another, limit its exercise to things at hand, to the sympa-

hovering at a great height; nor, in sweeping down upon his quarry, could he strike it with precision. Nothing of the nature of mere mechanical provision can account for the possession of this superior power. One instance of the power of adjustment which the eye has under the influence of the will seems to be this. Let a person who cannot read distinctly, or at all, without spectacles, at a given distance, look at a word through a very small aperture, and he will see what he before could not without spectacles. This can hardly be explained by the removal of the lateral light, or by inflexion.—ENG. ED.

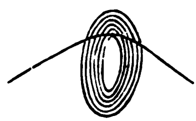
thies and affections of our nature visible in the countenance.

If we put aside the consideration of the living properties of the organ, as the extraordinary variety and degrees of sensibility in the nerve of vision, and confine ourselves to points easily comprehended, as, for example, the mechanism of the eye, and the laws of optics as applicable to the humors, we shall find enough to admire.

When we look upon the optician's lens, however perfect its polish may be, we can see its convex surface: that is to say, the rays of light, which strike upon that surface, do not all penetrate it, but are in part reflected to our eye, which is the occasion of our seeing it. We do not see the surface of the cornea of the human eye. Here, then, is an obvious superiority, since it implies that all the rays of light which strike the cornea, enter it and are refracted, and none are returned to our eye. If we take the optician's lens between our fingers and hold it under water, we can no longer see it, however transparent the water. The reason of this is, that the rays of light are reflected when entering from a rare medium into a denser, more abundantly in proportion to the difference of the density. When the ray of light has penetrated the water, it also penetrates the glass, because there is not that difference of density between the water and the glass which there is between the atmosphere and the glass. From this we may estimate the importance of the surface of the cornea being moistened by the tears; for, however thinly the water may be spread over the surface of the eye, it is sufficient to make those rays, that would otherwise be reflected, penetrate the cornea.

The whole humors of the eye are constituted with a regard to this law. There is no where an abrupt transition from a rare to a dense humor. The ray is transmitted from the cornea into the aqueous humor, and through that humor into the lens or crystalline humor. Were this latter humor uniform, and of the density of its central part, throughout, the ray would be in part reflected back from its surface. But it is not uniform, like a mass of glass: it consists of concentric layers, increasing in density from

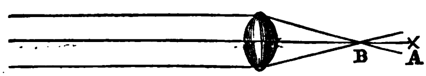
the surface to the centre. If we first look at the entire lens, and then take off its concentric layers, we shall see the surface of the internal nucleus more distinctly than the exterior and natural surface. The reason is obvious; the nucleus is so much more dense than the atmosphere, that the reflection of the rays from it is more abundant. We now comprehend how finely it is provided that the crystalline lens should be surrounded with the *liquor Morgagni*, a fluid which is but in a slight degree more dense than the aqueous humor. The exterior surface of the lens itself is only a little more dense than the surrounding fluid, and each successive layer, from the surface to the centre, is of gradually increasing density: so that if we were to describe the course of the ray, it would not, as we see in the ordinary diagrams, pass like a straight line of the pen,



but in a curved line, showing the gradual manner in which the ray is refracted through successive transparent layers. As it enters in the anterior half of its passage, it encounters media of increasing density: but as it passes out behind, it is transmitted through media diminishing in density. The ray is no where opposed by that sudden increase of density which gives a disposition to reflection; and it passes through the vitreous humor still refracted, the density of that humor having a just correspondence with the posterior surface of the lens. In the atmosphere there is a similar arrangement for receiving the light proceeding from the sun or stars: for, as the density of the air diminishes as the height above the earth increases, the surface of our atmosphere, from its rarity, must almost resemble free space; consequently, the light falling into it will penetrate more abundantly than if the air were compressed as it is near the earth, and were of uniform density. We thus see the obvious superiority in the structure of the eye to any thing that can be composed of glass, which is of *uniform density* throughout, and must therefore present a

succession of surfaces where rare and dense media are abruptly opposed to the rays transmitted.

We may observe another happy result from the peculiar structure of the lens. A magnifying glass is never true; an aberration of the rays takes place in the pencil of light, as the rays are drawn to a focus. The rays which penetrate near the centre are projected so as to be drawn to their focus beyond those rays which pierce through nearer the edge. The rays penetrating the centre of this double convex glass will project the image to A, whilst those penetrating nearer the circumference, and consequently falling more obliquely, will form a focus nearer the lens at B. But in the crystalline humor of the eye, which corresponds with the optician's lens, the exterior layer having less density, and therefore a diminished property of refracting the ray, the image is carried further off to A; and by this means it is ordered that wherever the ray penetrates, it shall be drawn to an accurate focus.



Some modern philosophers have asserted that the eye is not perfectly achromatic in every adjustment. The term implies the property of the instrument to represent an image divested of the prismatic colors—those false colors which attend the refraction of the rays of light. If the statement be correct, it is nothing against our argument; nor have those inquirers advanced it with any such view.* We know, that in all the ordinary exercises of the eye, the image is perfect, having neither penumbra nor prismatic colors. This property of the eye results from the different media through which the rays are transmitted, and the gradual transmission which we have just mentioned. Dollond's achromatic glasses, a great improvement upon the telescope, were made on this principle. He composed the object-glass of the telescope of crown-glass and flint-glass, so that while, by the combined effect of their con-

* Professor Blair (*Edinburgh Transactions*, iii.) expressly derives an argument in favor of design, from this statement of his opinion, and his objection to Boscovich.

vexities, they drew the rays to a focus, the dispersive power of the one was counteracted by that of the other.

Let us endeavor to explain this. A, a beam of light, being composed of the different colored rays, passes through the prism B. (See Fig. p. 80.) Instead of passing onward in a straight line, it is refracted to C in distinct, and, consequently, colored rays. Whilst the whole of them are bent or refracted at an angle from the dotted line, they are also diverging from one another. Their deviation from the straight line is their *refraction*: their diverging from each other is their *dispersion*. These properties being distinct, it is conceivable that glass of a different chemical composition may affect the one to a greater degree than the other, and, therefore, that a lens may be composed of different kinds of glass, (crown-glass and flint-glass, for example,) so that the convergence of rays into a focus may be obtained without the dispersion of the rays, and the consequent production of false colors round the image. This is what Dollond nearly accomplished, and upon these principles. That the effect of this very artificial arrangement is attained in the eye is a remarkable proof of the perfection of its adaptation to the properties of light.

The last circumstance which we may mention in continuing the comparison, is the drawing out of the tube in the telescope to accommodate the foci of the glasses to the distance of the object. It is sufficient to say that the eye possesses this property of accommodation. That we do not understand how the operation is performed, only strengthens the argument in favor of the perfection of the eye: since the power exists, and is exercised with an ease which hardly permits us to be sensible of it.*—SIR CHARLES BELL.]

* [The optician, alluded to by Dr. Paley, at page 83, is Mr. John Dollond, the first successful manufacturer of achromatic telescopes. It is not strictly correct to say that Mr. Dollond was led to his discovery by studying the arrangement of the human eye. The principle upon which the defect of the telescope, consisting of the colored image of the object, could be remedied, was well understood long before the time of Mr. Dollond's discovery. The difficulty had been to apply this principle in practice. Euler, in his celebrated and popular letters, says, it *it has been* remarked that this defect may be remedied by the employ-

Observe a new-born child first lifting up its eyelids. What does the opening of the curtain discover? The anterior part of two pellucid globes, which, when they come to be examined, are found to be constructed upon strict optical principles; the selfsame principles upon which we ourselves construct optical instruments. We find them perfect for the purpose of forming an image by refraction: composed of parts executing different offices; one part, having fulfilled its office upon the pencil of light, delivering it over to the action of another part; that to a third, and so onward: the progressive action depending for its success upon the nicest and minutest adjustment of the parts concerned: yet these parts so in fact adjusted as to produce, not by a simple action or effect, but by a combination of actions and effects, the result which is ultimately wanted. And forasmuch as this organ would have to operate under different circumstances, with strong degrees of light and with weak degrees, upon near objects and upon remote ones, and these differences demanded,

ment of different transparent substances. Euler himself attempted, though unsuccessfully, to get rid of the imperfection by employing lenses of glass containing water. It is an interesting fact, and one pertinent to this subject, that, before the uses and action of the different parts of the eye were fully understood, the structure of this organ had been pronounced, by atheistical reasoners, unnecessarily complicated, and from this source an argument had been derived adverse to the existence of a Supreme and All-wise Contriver. They said that a simple lens would have answered all the purposes of this complex apparatus, and a being, endowed with the attributes claimed for the Creator, would never have resorted to mechanism so complicated, in order to attain an end which might have been reached by more direct and simple means. This is far from being the first or only instance in which the atheistical conclusions, derived from false or incomplete science, have been converted, by more correct and complete knowledge, into the most striking and beautiful evidences of the existence and benevolence of a God.

The eye owes its perfection as an optical instrument, and its superiority over the telescope, to its combination of solid and fluid refracting bodies, to the different densities of the several concentric layers of the lens, and to the movable and self-adjusting curtain of the iris, corresponding to the fixed and less perfect diaphragm of the telescope. After all, no combination of human science and skill can do more than approach to the perfection of the eye.

For a biographical sketch of Dollond, see one of the volumes of THE SCHOOL LIBRARY, entitled, '*Pursuit of Knowledge under Difficulties.*'—*AM. ED.*]

according to the laws by which the transmission of light is regulated, a corresponding diversity of structure,—that the aperture, for example, through which the light passes, should be larger or less; the lenses rounder or flatter, or that their distance from the tablet, upon which the picture is delineated, should be shortened or lengthened: this, I say, being the case and the difficulty, to which the eye was to be adapted, we find its several parts capable of being occasionally changed, and a most artificial apparatus provided to produce that change. This is far beyond the common regulator of a watch, which requires the touch of a foreign hand to set it; but it is not altogether unlike Harrison's contrivance for making a watch regulate itself, by inserting within it a machinery, which, by the artful use of the different expansion of metals, preserves the equability of the motion under all the various temperatures of heat and cold in which the instrument may happen to be placed. The ingenuity of this last contrivance has been justly praised. Shall, therefore, a structure, which differs from it chiefly by surpassing it, be accounted no contrivance at all? or, if it be a contrivance, that it is without a contriver?

But this, though much, is not the whole: by different species of animals, the faculty we are describing is possessed, in degrees suited to the different range of vision which their mode of life, and of procuring their food, requires. *Birds*, for instance, in general, procure their food by means of their beak; and, the distance between the eye and the point of the beak being small, it becomes necessary that they should have the power of seeing very near objects distinctly. On the other hand, from being often elevated much above the ground, living in the air, and moving through it with great velocity, they require for their safety, as well as for assisting them in descrying their prey, a power of seeing at a great distance; a power, of which, in birds of rapine, surprising examples are given. The fact accordingly is, that two peculiarities are found in the eyes of birds, both tending to *facilitate* the change upon which the adjustment of the eye to *different distances* depends. The one is a bony, yet, in

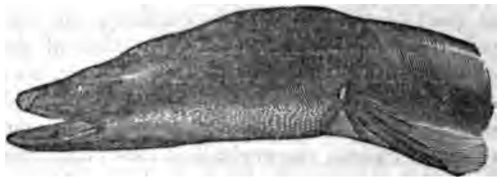
most species, a flexible rim or hoop surrounding the broadest part of the eye, which, confining the action of the muscles to that part, increases the effect of their lateral pressure upon the orb, by which pressure, its axis is elongated for the purpose of looking at very near objects. The other is an additional muscle, called the marsupium, to draw, on occasion, the crystalline lens *back*, and to fit the same eye for the viewing of very distant objects. By these means, the eyes of birds can pass from one extreme to another of their scale of adjustment, with more ease and readiness than the eyes of other animals.*

The eyes of *fishes* also, compared with those of terrestrial animals, exhibit certain distinctions of structure, adapted to their state and element. We have already observed upon the figure of the crystalline lens compensating by its roundness the density of the medium through which their light passes. To which we have to add, that the eyes of fish, in their natural and indolent state, appear to be adjusted to near objects, in this respect differing from the human eye, as well as those of quadrupeds and birds. The ordinary shape of the fish's eye being in a much higher degree convex than that of land animals, a corresponding difference attends its muscular conformation, viz., that it is throughout calculated for *flattening* the eye.

The *iris* also in the eyes of fish does not admit of contraction. This is a great difference, of which the probable reason is, that the diminished light in water is never too strong for the retina.

In the *eel*, which has to work its head through sand

* [The mechanism and action by which the eye adjusts itself to objects, at different distances from it, are not yet satisfactorily ascertained, although the subject has engaged the attention of many distinguished philosophers and physiologists, among whom may be mentioned Kepler, Descartes, Blumenbach, Haller, Biot, Sir David Brewster, and Sir Charles Bell. It is due to the truth, that this statement should be made, although the argument of Dr. Paley, founded upon this particular point, is in no way affected by it. It is sufficient for the argument, that the adjustment is, in some way, made; and the fact that the necessary end is attained, through an arrangement of parts so exquisitely nice and subtile as to elude the closest scrutiny of human genius, ought to increase rather than diminish our admiration of the skill of the Divine *Contriver.—Am. Ed.*]



and gravel, the roughest and harshest substances, there is placed before the eye, and at some distance from it, a transparent, horny, convex case or covering, which, without obstructing the sight, defends the organ. To such an animal could any thing be more wanted or more useful?

Thus, in comparing the eyes of different kinds of animals, we see in their resemblances and distinctions one general plan laid down, and that plan varied with the varying exigencies to which it is to be applied.[6]

[6] In viewing the structure of the eye as adjusted to the condition of fishes, we may remark the peculiar thickness of the sclerotic coat in the whale. Although he breathes the atmosphere, and lies out on the surface of the water; to escape his enemies he will plunge some hundred fathoms deep. The pressure therefore must be very great upon his surface, and on the surface of the eye. If a cork be knocked into the mouth of a bottle, so that it resists all further pressure that we can make upon it, and if this bottle be carried, by being attached to the sounding-lead, to a great depth in the sea, the pressure of the water will force in the cork, and fill the bottle; for the cork is pressed with a force equal to the weight of the column of water above it, of which it is the base. It is pressed in all directions equally, so that a common-sized cork is reduced to the size of that of a phial bottle.

"A creature living at the depth of 100 feet, would sustain a pressure, including that of the atmosphere, of about 60 pounds on a square inch; while one at 4000 feet, a depth by no means considerable, would be exposed to a pressure of about 1830 pounds upon the square inch."—*De La Beche, Theor. Geol.* p. 243.

We can therefore comprehend how it shall happen, that on the foundering of a ship at sea, though its timbers part, not a spar floats to the surface; every thing is swallowed up; for, if the hull has sunk to a great depth, all that is porous is penetrated with water, or compressed, and consequently remains where it sunk. So it happened, and the fact goes directly to our purpose, that when, by the entangling of the line of the harpoon, the boat was carried down with the whale, and, being recovered, it required two boats to keep it at the surface.—*Scoresby.*

We may easily conceive, therefore, the pressure which the eye of *the whale* sustains when it dives, and why it is formed with the pro-

There is one property, however, common, I believe, to all eyes, at least to all which have been examined,* namely, that the optic nerve enters the bottom of the eye, not in the centre or middle, but a little on one side; not in the point where the axis of the eye meets the retina, but between that point and the nose. The difference which this makes is, that no part of an object is unperceived by both eyes at the same time.

In considering vision as achieved by the means of an image formed at the bottom of the eye, we can never reflect without wonder upon the smallness yet correctness of the picture, the subtilty of the touch, the fineness of the lines. A landscape of five or six square leagues is brought into a space of half an inch diameter; yet the multitude of objects which it contains are all preserved, are all discriminated in their magnitudes, positions, figures, colors. The prospect from Hampstead-hill is compressed into the compass of a sixpence, yet circumstantially represented. A stagecoach, travelling at an ordinary speed for half an hour, passes, in the eye, only over one-twelfth of an inch, yet is this change of place in the image distinctly perceived throughout its whole progress; for it is only by means of that perception that the motion of the coach itself is made sensible to the eye. If any thing can abate our admiration of the smallness of the visual

visions which we are about to describe. When we make a section of the whole eye, cutting through the cornea, the sclerotic coat, which is dense as tanned leather, increases in thickness towards the back part, and is full five times the thickness behind, that it is at the anterior part. The anterior part of the eye sustains the pressure from without, and requires no additional support; but were the back part to yield, the globe would be then distended in that direction, and the whole interior of the eye consequently suffer derangement. We perceive, therefore, the necessity of the coats being thus so remarkably strengthened behind. The natural enemies of the whale are the sword-fish and the shark; and it is stated, with some show of reason, that this huge creature, being without means of defence of any kind, carries his enemies, that have fixed upon him, to a depth of water, and consequently to a pressure, which subdues them, as their bodies are not constituted for such depths. It is under this instinct, that when the whale receives the harpoon, he dives to the bottom.—ENG. ED.

* The eye of the seal or sea-calf, I understand, is an exception. Mem. Acad. Paris, 1701, p. 123.—PALEY.

tablet compared with the extent of vision, it is a reflection which the view of nature leads us every hour to make, viz., that in the hands of the Creator great and little are nothing.

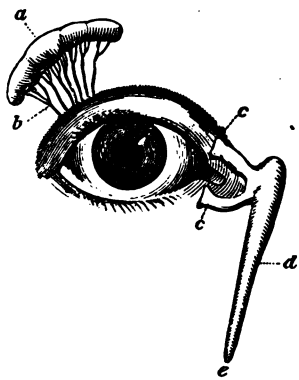
Sturmius held, that the examination of the eye was a cure for atheism. Besides that conformity to optical principles which its internal constitution displays, and which alone amounts to a manifestation of intelligence having been exerted in the structure; besides this, which forms, no doubt, the leading character of the organ, there is to be seen, in every thing belonging to it and about it, an extraordinary degree of care, an anxiety for its preservation, due, if we may so speak, to its value and its tenderness. It is lodged in a strong, deep, bony socket, composed by the junction of seven different bones,* hollowed out at their edges. In some few species, as that of the coatimondi,† the orbit is not bony throughout; but whenever this is the case, the upper, which is the deficient part, is supplied by a cartilaginous ligament; a substitution which shows the same care. Within this socket it is imbedded in fat, of all animal substances the best adapted both to its repose and motion. It is sheltered by the eyebrows—an arch of hair, which, like a thatched penthouse, prevents the sweat and moisture of the forehead from running down into it.

But it is still better protected by its *lid*. Of the superficial parts of the animal frame, I know none which, in its office and structure, is more deserving of attention than the eyelid. It defends the eye; it wipes it; it closes it in sleep. Are there, in any work of art whatever, purposes more evident than those which this organ fulfils? or an apparatus for executing those purposes more intelligible, more appropriate, or more mechanical? If it be overlooked by the observer of nature, it can only be because it is obvious and familiar. This is a tendency to be guarded against. We pass by the plainest instances, whilst we are exploring those which are rare and curious; by which conduct of the understanding, we sometimes neglect the strongest observations, being taken

* *Heister*, sect. 89. † Mem. R. Ac. Paris, p. 117.—PALEY.

up with others which, though more recondite and scientific, are, as solid arguments, entitled to much less consideration.

In order to keep the eye moist and clean, (which qualities are necessary to its brightness and its use,) a wash is constantly supplied by a secretion for the purpose; and the superfluous brine is conveyed to the nose through a perforation in the bone as large as a goose-quill. When



[This cut represents the apparatus for moistening the eye, and for carrying off the tears. *a*, the gland which secretes or forms the tears. *b*, small ducts or tubes which convey the tears from the gland, and discharge them upon the globe of the eye. *c*, *c*, minute openings or orifices, called the *puncta lachrymalia*, through which the tears enter into the canal which transmits them to the nostrils; these little openings can be easily seen on the edges of the lids near the inner corner of the eye. *d*, the duct or canal through which the tears are carried down from the eye to the inside of the nostrils.—AM. ED.]

once the fluid has entered the nose, it spreads itself upon the inside of the nostril, and is evaporated by the current of warm air which, in the course of respiration, is continually passing over it. Can any pipe or outlet, for carrying off the waste liquor from a dye-house or a dis-

tillery, be more mechanical than this is? It is easily perceived that the eye must want moisture; but could the want of the eye generate the gland which produces the tear, or bore the hole by which it is discharged—a hole through a bone?

It is observable that this provision is not found in fish,—the element in which they live supplying a constant lotion to the eye.

[OF THE MEANS BY WHICH THE EYE IS PROTECTED.

When an astronomer, in the darkness of night, and shaded from the light of his chamber, moves his telescope from star to star, his eye is accommodated to faint impressions; that is, the sensibility of the retina is then accumulated, so that when he directs his instrument to the brighter objects his sensation is painful. And if, at another time, he should be observing the sun, without having guarded the eye by smoking the glasses, or by some other means diminishing their transparency,—the stroke upon the retina will not only be painful, but may prove destructive to its fine texture, and occasion a defect of vision which will continue through life. If the apparatus in the tympanum of the ear be destroyed, and the defect supplied by an ear-trumpet, the person will be startled by those who speak into this trumpet: for, if they are not in the habit of pitching their voices distinctly and softly, the sound will jar painfully upon his ear. By these considerations, we are prepared to contemplate that beautiful provision by which the natural eye is protected against the sudden intrusion of light, or the too intense illumination of the object upon which it is directed.

The iris is a curtain, or septum, which stretches across the aqueous humor, and is anterior to the crystalline lens: it is perforated in the centre, and that perforation is the pupil—the black central spot which we see when we look into the eye,—black, for the reason which we have assigned, that the rays piercing there are not returned, and the absence of rays is blackness. But the rays strike the anterior part of the iris itself round the perforation,

and they are partially, at least, reflected, giving the color to the eye,—gray, or blue, or hazel.

Perhaps the diagram, (on page 84,) will explain the structure of the iris and pupil; and show the mode in which the pencil of rays is enlarged or diminished, and the intensity of the image in the eye thus made greater or less in proportion to the illumination.

The iris, then, we understand to be a muscular septum or partition, with two sets of fibres; a straight set, converging to that margin of the iris which forms the pupil, and a circular set, running round the exterior margin of the iris. At page 290, of this volume, we have given a representation of the iris of the lion. The pupil or open space is oval in this animal; B B are the straight fibres converging to the exterior margin of the iris; and C C are the circular fibres of the margin. These two sets of fibres act against each other, and in a moderate light the pupil is moderately expanded; but when the light is obscure, the circular fibres relax, and the straight fibres act: the iris is then diminished in diameter, and the pupil enlarged. The contrary takes place when too intense a light strikes into the eye.

This guardian action of the iris is more rapid than words, and as quick as thought; and it is to be remarked that this apparatus is animated by nerves which go back to the sensorium: so that the impression must be received in the sensorium before the iris can be directed in its motions.

Such, then, is the apparatus by which the nerve of vision is guarded; and, as marking its necessity, let us remember, that the retina is susceptible, in an extraordinary degree, of various impressions of light; that it will be sensible to an object illuminated as one, and as thirty thousand. It is obvious, that either we must have groped in the dark during the evening or moonlight, or have been quite dazzled and overpowered by the brightness of the sun, had not this fine mechanical apparatus of the iris been adapted and assigned for the protection of the nerve.

But the nerve is protected in another way, or rather,

we should say, the force of the impression is regulated. We have seen that the colors of objects are owing to the rays of light being reflected from them; that on a surface perfectly black, the rays sink in and are lost, and we recognise the object only by its outline being contrasted with surrounding colored bodies, not by the light reflected from itself. When the eye of an animal is destined for the bright light of day, a black pigment is behind the nerve, and the nerve itself being transparent, the ray is transmitted and lost. But if it be required that the eye shall be suited to the habits of an animal that prowls by night, then there is combined with the large eye and the very dilatable pupil, calculated to receive a great pencil of rays, a property of reflection in the *tapetum* or carpet, that is, the surface at the bottom of the eye on which the nerve is expanded. Instead of the black and absorbing pigment, there is a secretion furnished by that surface, which, like a dye, throws off or reflects the light, or reflects it back like the silver on the back of a mirror. This gives a second impulse to the nerve, and has the effect of doubling the force of the impression.

Let us now see how an organ of the extreme transparency and delicacy of the eye is guarded from injuries of another kind.

And, first, we may observe the combination of the living properties with the motion and mechanism of the eyeball; how the extreme delicacy of the surfaces of the eye has adapted to it the fine sensibility seated in the eyelids and roots of the eyelashes. The pain excited by the smallest particle that floats in the atmosphere would be the source of constant suffering, were there not connected with, and animated by, the same sensibility, an apparatus, mechanical and hydraulic, for the obvious purpose of ridding the delicate surface of the eye of all foreign matter.

Can there be any thing more interesting than to find the whole of this apparatus under the guidance of a property *different* from that of consciousness and volition?

I have seen many instances of persons deprived of the

sensibility of the surfaces of the eye from the affection of one nerve alone, without the loss of vision, or of the motions of the eyelids, or of the flow of tears; but it has been impossible in such persons to preserve the organ, by assuring them of the necessity of these motions, either through the direct action of the eyelids, or by the aid of their fingers. The eye's surfaces, being deprived of sensation, are no longer regularly moistened: soot and dust rest upon them; and although they are insensible, they inflame; the transparent cornea becomes opaque, and the eye is lost. This is the consequence neither of the want of sensibility in the retina, nor of the capacity of motion in the eyeball and eyelids being lost, nor of failure of the spring of water that runs continually over the eye: it results simply from a loss of that relation in the sensibilities suited to the materials and influences around us, and the protecting motions which they excite. It at once answers the querist who asks, why we suffer pain. We reply to him by another question—How are we to hear or see, or how enjoy the sense from impressions so delicate as those of sound and light; or enjoying these, by instruments so exquisitely framed, how are these instruments to be protected from the ruder shocks to which they must be exposed? These considerations lead to the conclusion that if he object to one part of the system, he objects to the whole of that by which we hold our present existence.

The motions of the eye and eyelids, which are directed by this sensibility, must be performed with extreme rapidity. To rinse any thing in water, or to rid it of dust by shaking it in the wind, the action must be quick; and such a motion is possessed by the eye of the fish, although the eyelids and lachrymal apparatus are in them unnecessary.

If we are giving proofs of design, we can have none more obvious than that in the eye of the mud crab, an animal which, like the eel, seeks its food in mud and turbid water. Emerging from such a bed, its eye is covered with slime, and would be useless: but to provide against this inconvenience there is a little brush near the eye, to

which the prominent horny eye can be raised, and against which it is wiped, with an action as intelligible as that of a man wiping his spectacles. The cray-fish, too, which burrows in the banks of rivers,, has the same provision, although the structure is less perfect.

I have assumed, that the action of the eye of fishes is rapid. I must confess, that I have not seen this, but we are entitled to conclude that they possess the motion, as fishes have other muscles besides those necessary to direct the eye; muscles which, by the oblique direction of their fibres, are calculated to give extraordinary rapidity of motion, and resemble that apparatus which gives the rapid instinctive motions to our own eye.

The first time that we observe any remarkable phenomena, they excite more emotion, and we describe them with more interest. I shall therefore extract here a portion of a paper given to the Royal Society on the nerves of the eye, which it was necessary to preface by observations on the actions of the muscles, a subject which I conceived had not been fully understood.

MOTIONS OF THE EYEBALL AND EYELIDS.

We shall consider the muscles of the eye, first, as necessary to its preservation; secondly, as necessary to it as the organ of sense. We do not reflect on those actions of our frame which are most admirable in themselves, which minister continually to our necessities, and perfect the exercise of our organs, until we are deprived of them: like unnatural children, unconscious or unmindful of indulgence, we feel only the loss of benefits. "With much compassion," says the religious philosopher, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of those two little muscles that serve to lift up the eyelids, and so had almost lost the use of his sight, being forced, as long as this defect lasted, to *shove up his* eyelids with his own hands." I have often

thought of this saying, when I have seen a patient in all respects in health, but without the power of raising the eyelids.

There is a motion of the eyeball, which, from its rapidity, has escaped observation. In the instant that the eyelids are closed, the eyeball makes a movement which raises the cornea under the upper eyelid.

If we fix one eye upon an object, and close the other eye with the finger, so as to feel the convexity of the cornea through the eyelid, we shall perceive when we shut the eye that is open, that the cornea of the other eye is instantly elevated ; and that it thus rises and falls in sympathy with the eye that is closed and opened. This change of the position of the eyeball takes place during the most rapid winking motions of the eyelids. When a dog was deprived of the power of closing the eyelids of one eye by cutting across the nerve of the eyelids, the eye did not cease to turn up when he was threatened, and when he winked with the eyelids of the other side.

Nearly the same thing I observed in a girl, whose eyelids were attached to the surrounding skin, owing to a burn ; for the forepart of the eyeball being completely uncovered, when she would have winked, instead of the eyelids descending, the eyeballs were turned up, and the cornea was moistened by coming in contact with the mouths of the lachrymal duct.

The purpose of this rapid insensible motion of the eyeball will be understood by observing the form of the eyelids and the place of the lachrymal gland. The margins of the eyelids are flat, and when they meet, they touch only at their outer edges, so that when closed there is a gutter left between them and the cornea. If the eyeball were to remain without motion, the margins of the eyelids would meet in such a manner on the surface of the cornea, that a certain portion would be left untouched, and the eye would have no power of clearing off what obscured the vision, at that principal part of the lucid cornea which is in the very axis of the eye ; and if the tears flowed, they would be left accumulated on the centre of the cornea, and winking, *instead* of clearing the eye, would suffuse

it. To avoid these effects, and to sweep and clear the surface of the cornea, at the same time that the eyelids are closed, the eyeball revolves, and the cornea is rapidly elevated under the eyelid.

Another effect of this motion of the eyeball is to procure the discharge from the lachrymal ducts ; for, by the simultaneous ascent of the cornea, and descent of the upper eyelid, the membrane on which the ducts open is stretched, and then the tears flow unimpeded.

By this simultaneous motion, also,—the descent of the eyelid and the ascent of the cornea,—the rapidity with which the eye escapes from injury, is increased. Even creatures which have imperfect eyelids, as fishes, by possessing this rapid revolving motion of the eye, avoid injury and clear off impurities.

I may observe, in passing, that there is a provision for the protection of the eye, in the manner in which the eyelids close, which has not been noticed. While the upper eyelid falls, the lower eyelid is moved towards the nose. This is a part of that curious provision for collecting offensive particles towards the inner corner of the eye. If the edges of the eyelids be marked with black spots, it will be seen, that when the eyelids are opened and closed, the spot on the upper eyelid descends and rises perpendicularly, while the spot on the lower eyelid will play horizontally like a shuttle.

To comprehend these actions of the muscles of the eye, we must remember that the caruncle and membrane called *semilunaris*, seated in the inner corner of the eye, are for ridding the eye of extraneous matter, and are, in fact, for the same purpose as that apparatus which is more perfect in beasts and birds. The tears are imbibed by the *puncta* or orifices, which may be seen in the inner corner of the eye ; and a tube, formed on the principle of a siphon, carries them into the nose ; whilst the dust, washed to this corner, is thrown out by the apparatus which we have described.

The course of our inquiry makes some notice of these parts necessary.

In quadrupeds, there is a gland for secreting a glutinous

and adhesive fluid, seated on the side of the orbit next the nose: it is quite distinct from the lachrymal gland; it is squeezed by an apparatus of muscles, and the fluid exudes upon the surface of the third eyelid. This third eyelid is a very peculiar part of the apparatus of protection. It is a thin cartilage, the posterior part of which, is attached to an elastic body. This body is lodged in a division or depression of the orbit on the side towards the nose. When the eye is excited, the eyeball is made to press on the elastic body, against the side of the orbit, and force it out of its recess or socket; the consequence of which is the protrusion of the cartilaginous third eyelid, or *haw*, as it is termed in the horse. By this mechanism, the third eyelid is made to sweep rapidly over the surface of the cornea, and, by means of the glutinous fluid with which its surface is bedewed, it attaches to itself and clears away offensive particles.

In birds, the eye is an exquisitely fine organ, and still more curiously, we might be tempted to say artificially, protected. The third eyelid is more perfect than that of quadrupeds: it is membranous and broad, and is drawn over the surface of the eye by means of two muscles attached to the back part of the eyeball, one of which acts by a long round tendon, that makes a course of nearly three parts of the circumference of the ball.* The lachrymal gland is small, and seated low, but the mucous gland is of great size, and placed in a cavity deep and large, and on the inside of the orbit. As the third eyelid is moved by an apparatus, which cannot squeeze the mucous gland at the same time that the eyelid is moved, as in quadrupeds, the oblique muscles are particularly provided to draw the eyeball against the gland, and to force out the mucus on the surface of the third eyelid. It flows very copiously; and this is probably the reason of the smallness of the proper lachrymal gland, which lies on the opposite side of the orbit.

We already see two objects attained through the motion of these parts: the moistening of the eye with the clear

* See p. 112, of this volume.

fluid of the lachrymal gland, and the extraction or protrusion of offensive particles.

There is another part of this subject, no less curious,—the different conditions of the eye during the waking and sleeping state. If we approach a person in disturbed sleep, when the eyelids are a little apart, we shall not see the pupil or the dark part of the eye, as we should were he awake, for the cornea is turned upwards under the upper eyelid. If a person be fainting, as insensibility comes over him the eyes cease to have speculation ; they want direction, and are vacant, and presently the white part of the eye is disclosed by the revolving of the eyeball upwards. Look to a blind beggar ; those white balls are not turned up in the fervor of entreaty ; it is the natural state of the eyeballs, which are totally blind, and from the exercise of which the individual has withdrawn his attention. So it is on the approach of death ; for, although the eyelids be open, the pupils are in part hid, being turned up with a seeming agony, which, however, is the mark of increasing insensibility. These motions of the eye for the protection of the organ do not interfere with vision ; they are performed unconsciously, and so rapidly that the impression of the object on the retina has not time to vanish in the interval. The motions of the eyeball, for directing the eye to objects, are strictly voluntary, and are always connected with the exercise of the sense of vision.

It will now be admitted, that the variety of the motions of the eye, requires the complication of muscles which we find in the orbit, and unless the various offices and different conditions of the eye be considered, it would be in vain to attempt an accurate classification of the muscles or nerves of the orbit.

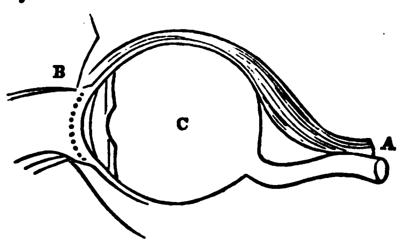
MUSCLES OF THE EYELIDS.

Even in the action of the muscles of the eyelids, although the most exposed and familiar parts of any, there is something new, still to be observed. The eyeball is held betwixt the *levator palpebræ*, the muscle which raises

the eyelid, and the *orbicularis*, that which depresses it; the one as it elevates the eyelid tending to protrude the eyeball, the other to compress and restrain it.

In paralysis of the *orbicularis*, the muscle which closes the eye, the eyeball is protruded; it starts more forward than is natural; the eyelid is loose and flabby, and can be lifted like a bit of common skin.

It is from this protrusion of the eyeball that the upper eyelid is raised, and the lower eyelid depressed, by one muscle. Anatomists have sought for a depressor of the inferior eyelid, seeing that is depressed; but such a muscle has no existence, and is quite unnecessary. The *levator palpebræ superioris* opens wide the eyelids, depressing the lower eyelid at the same time that it elevates the upper one. If we put the finger upon the lower eyelid so as to feel the eyeball when the eye is shut, and then open the eye, we shall perceive that, during this action, the eyeball is pushed forwards. Now the lower eyelid is so adapted as to slip off the convex surface of the ball in this action, and thus to be depressed, while the upper eyelid is elevated.



The origin of the levator being at A, and the insertion into the cartilage of the upper eyelid at B, the effect of the action of the muscle must be the protrusion of the eyeball C to the dotted line. By the elevation of the upper eyelid, the eye starts forward a little, and the lower eyelid therefore slips off the lower segment of the eyeball.

It is curious to observe, how the eyeball retreats in its condition of repose, and is protruded when about to be exercised in vision. High excitement, as in terror, *when the eyeballs* are largely unclosed, is attended with

an increase of the sphere of vision produced by the protrusion of the eyeballs; a change remarkable both in the ferocious and timid animals, especially in the latter.

Such were the views of the motions of the eyeball and eyelids, introductory to a paper on the muscles of the eye,—itself introductory to observations on the nerves of the orbit. The discussion relating to these, is too strictly and minutely anatomical for our present purpose. It will be sufficient if I state the deduction,—that by the eight muscles around the eye, and the six nerves, whose extremities reach them, two sets of motions are provided; the first, for the voluntary direction of the eyeball in strict sympathy with vision; the other, in connexion with the mechanical and hydraulic apparatus, for the protection of the organ. When we enjoy the sense of vision, the voluntary muscles are excited; but, in sleep, another class preponderates, over which we have no voluntary power; and this is the condition of rest as well as of safety to the organ.—SIR CHARLES BELL.]

It were, however, injustice to dismiss the eye as a piece of mechanism, without noticing the most exquisite of all contrivances, the *nictitating membrane*, which is found in the eyes of birds, and of many quadrupeds. Its use is to sweep the eye, which it does in an instant; to spread over it the lachrymal humor; to defend it also from sudden injuries; yet not totally, when drawn upon the pupil, to shut out the light. The commodiousness with which it lies folded up in the upper corner of the eye, ready for use and action, and the quickness with which it executes its purpose, are properties known and obvious to every observer; but what is equally admirable, though not quite so obvious, is the combination of two kinds of substance, muscular and elastic, and of two different kinds of action, by which the motion of this membrane is performed. It is not, as in ordinary cases, by the action of two antagonist muscles, one pulling forward, and the other backward, that a reciprocal change is effected; but it is thus: the membrane itself is an elastic substance, capable of being drawn out by force like a piece of elastic gum, and by its own elasticity returning,

when the force is removed, to its former position. Such being its nature, in order to fit it up for its office, it is connected by a tendon or thread with a muscle in the back part of the eye: this tendon or thread, though strong, is so fine as not to obstruct the sight, even when it passes across it; and the muscle itself, being placed in the *back* part of the eye, derives from its situation the advantage, not only of being secure, but of being out of the way; which it would hardly have been in any position that could be assigned to it in the anterior part of the orb, where its function lies. When the muscle behind the eye contracts, the membrane, by means of the communicating thread, is instantly drawn over the forepart of it. When the muscular contraction (which is a positive, and, most probably, a voluntary effort) ceases to be exerted, the elasticity alone of the membrane brings it back again to its position.* Does not this, if any thing can do it, bespeak an artist, master of his work, acquainted with his materials? "Of a thousand other things," say the French Academicians, "we perceive not the contrivance, because we understand them only by their effects, of which we know not the causes; but we here treat of a machine, all the parts whereof are visible, and which need only be looked upon to discover the reasons of its motion and action."†

In the configuration of the muscle which, though placed behind the eye, draws the nictitating membrane over the eye, there is, what the authors just now quoted deservedly call a marvellous mechanism. I suppose this structure to be found in other animals; but, in the memoirs from which this account is taken, it is anatomically demonstrated only in the cassowary. The muscle is *passed though a loop formed by another muscle*; and is there inflected as if it were round a pulley. This is a peculiarity, and observe the advantage of it. A single muscle with a straight tendon, which is the common muscular form, would have been sufficient, if it had had power to draw far enough. But the contraction necessary to draw

* Phil. Trans. 1796.

† Memoirs for a Natural History of Animals, by the Royal Academy of Sciences at Paris, done into English by order of the Royal Society, 1701, p. 249.—PALEY.

the membrane over the whole eye, required a longer muscle than could lie straight at the bottom of the eye. Therefore, in order to have a greater length in a less compass, the cord of the main muscle makes an angle. This so far answers the end; but, still further, it makes an angle, not round a fixed pivot, but round a loop formed by another muscle, which second muscle, whenever it contracts, of course twitches the first muscle at the point of inflection, and thereby assists the action designed by both.[7]

One question may possibly have dwelt in the reader's mind during the perusal of these observations, namely, Why should not the Deity have given to the animal the faculty of vision *at once?* Why this circuitous perception; the ministry of so many means; an element provided for the purpose; reflected from opaque substances, refracted through transparent ones; and both according to precise laws; then, a complex organ, an intricate and artificial apparatus, in order, by the operation of this element, and in conformity with the restrictions of these laws, to produce an image upon a membrane communicating with the brain? Wherefore all this? Why make the difficulty in order to surmount it? If to perceive objects by some other mode than that of touch, or objects which lay out of the reach of that sense, were the thing proposed, could not a simple volition of the Creator have communicated the capacity? Why resort to contrivance, where power is omnipotent? Contrivance, by its very definition and

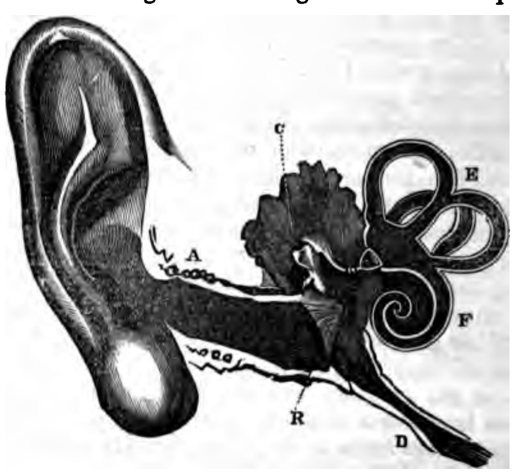
[7] There is one effect, however, of this apparatus, which our author has omitted to notice,—that is, the rapidity of motion in the *membrana nictitans*, produced by the oblique direction and junction of the tendons of these muscles. This will be illustrated hereafter.

The *membrana nictitans* is peculiar to birds: the term is not applicable to the corresponding structure in quadrupeds, the object being there obtained by a very different mechanism. The *haw* is a thin cartilage, which, lying between the eyeball and the inner part of the orbit, flies rapidly out, and sweeps the surface of the eye in a manner much more perfect than can be performed by the outer eyelids. Every one who has ridden a horse in a dusty road, must have been struck with the superior provision in the horse's eye: he never suffers from the dust, because this cartilage, being bedewed by the secretion of a peculiar *gland, not tears*, but a matter more glutinous, sweeps across the eye, *and collects* and removes every particle of dust.—Eng. Ed.

nature, is the refuge of imperfection. To have recourse to expedients implies difficulty, impediment, restraint, defect of power. This question belongs to the other senses, as well as to sight; to the general functions of animal life, as nutrition, secretion, respiration; to the economy of vegetables; and indeed to almost all the operations of nature. The question, therefore, is of very wide extent; and amongst other answers which may be given to it, besides reasons of which probably we are ignorant, one answer is this: It is only by the display of contrivance that the existence, the agency, the wisdom of the Deity, *could* be testified to his rational creatures. This is the scale by which we ascend to all the knowledge of our Creator which we possess, so far as it depends upon the phenomena, or the works of Nature. Take away this, and you take away from us every subject of observation, and ground of reasoning; I mean, as our rational faculties are formed at present. Whatever is done, God could have done without the intervention of instruments or means; but it is in the construction of instruments, in the choice and adaptation of means, that a creative intelligence is seen. It is this which constitutes the order and beauty of the universe. God, therefore, has been pleased to prescribe limits to his own power, and to work his ends within those limits. The general laws of matter have, perhaps, prescribed the nature of these limits; its inertia, its reaction; the laws which govern the communication of motion, the refraction and reflection of light, the constitution of fluids non-elastic, the transmission of sound through the latter; the laws of magnetism, of electricity; and probably others, yet undiscovered. These are general laws; and when a particular purpose is to be effected, it is not by making a new law, nor by the suspension of the old ones, nor by making them wind, and bend, and yield to the occasion; (for Nature, with great steadiness, adheres to and supports them;) but it is, as we have seen in the eye, by the interposition of apparatus, corresponding with these laws, and suited to the exigency which results from them, that the purpose is at length attained. As we have said, therefore, God prescribes limits to his power, that He may let in the

exercise and thereby exhibit demonstrations of his wisdom. For then, *i. e.*, such laws and limitations being laid down, it is as though one Being should have fixed certain rules, and, if we may so speak, provided certain materials, and afterwards have committed to another Being, out of these materials, and in subordination to these rules, the task of drawing forth a creation: a supposition which evidently leaves room, and induces indeed a necessity for contrivance. Nay, there may be many such agents, and many ranks of these. We do not advance this as a doctrine either of philosophy or of religion; but we say that the subject may safely be represented under this view; because the Deity, acting Himself by general laws, will have the same consequences upon our reasoning, as if He had prescribed these laws to another. It has been said, that the problem of creation was, "attraction and matter being given, to make a world out of them;" and, as above explained, this statement perhaps does not convey a false idea.

We have made choice of the eye as an instance upon which to rest the argument of this chapter. Some single example was to be proposed; and the eye offered itself under the advantage of admitting of a strict comparison



with optical instruments. The ear, it is probable, is no less artificially and mechanically adapted to its office than the eye. But we know less about it: we do not so well understand the action, the use, or the mutual dependency of its internal parts. Its general form, however, both external and internal, is sufficient to show, that it is an instrument adapted to the reception of *sound*; that is to say, already knowing that sound consists in pulses of the air, we perceive, in the structure of the ear, a suitableness to

[*Explanation of the plan of the Ear.*—A, the tube of the ear, having little glands to secrete the wax, and hairs standing across it to exclude insects, without impeding the vibrations of the atmosphere; B, the membrane of the *tympanum* drawn into the form of a funnel by the attachment of the *malleus*; C, the chain of four bones lying in the irregular cavity of the *tympanum*, and communicating the vibrations of the membrane B, to the fluid in the labyrinth; D, Eustachian tube, which forms a communication between the throat and the *tympanum*, so as to preserve an equilibrium of the air, in the cavity of the *tympanum* and the atmosphere; E, F, the labyrinth, consisting of a central cavity, the vestibule; the three semicircular canals, E, and the *cochlea*, F.

Beginning from the left hand, we have the *malleus*, or hammer, the first of the chain of bones; we see the long handle or process, which is attached to the membrane of the *tympanum*, and which moves with the vibrations of that membrane; the other end is enlarged, and has a groove upon it which is articulated with the next bone. The second bone is the *incus*, or anvil, to the grooved surface of which the *malleus* is attached. A long process extends from this bone, which has upon it the *os orbiculare*; and to this third bone there is attached a fourth, the *stapes*, which is in shape like a stirrup-iron. The base of this bone is of an oval shape, and rests upon a membrane which closes the hole leading into the labyrinth. This hole is called *foramen ovale*. The plan of the *cochlea* shows that one of its spiral passages, beginning in the vestibule, winds round the pillar till it meets in a point with another tube. If the eye follow this second spiral tube, it will be found to lead, not into the vestibule, but into the irregular cavity of the *tympanum*.]

receive impressions from this species of action, and to propagate these impressions to the brain. For of what does this structure consist? An external ear, (the concha,) calculated, like an ear-trumpet, to catch and collect the pulses of which we have spoken; in large quadrupeds, turning to the sound, and possessing a configuration, as well as motion, evidently fitted for the office: of a tube which leads into the head, lying at the root of this outward ear, the folds and sinuses thereof tending and conducting the air towards it: of a thin membrane, like the pelt of a drum, stretched across this passage upon a bony rim: of a chain of movable and infinitely curious bones, forming a communication, and the only communication that can be observed, between the membrane last mentioned, and the interior channels and recesses of the skull: of cavities, similar in shape and form to wind instruments of music, being spiral or portions of circles: of the Eustachian tube, like the hole in a drum, to let the air pass freely into and out of the barrel of the ear, as the covering membrane vibrates, or as the temperature may be altered: the whole labyrinth hewn out of a rock; that is, wrought into the substance of the hardest bone of the body. This assemblage of connected parts constitutes together an apparatus, plainly enough relative to the transmission of sound, or of the impulses received from sound, and only to be lamented in not being better understood.

The communication within, formed by the small bones of the ear, is, to look upon, more like what we are accustomed to call machinery, than any thing I am acquainted with in animal bodies. It seems evidently designed to continue towards the sensorium the tremulous motions which are excited in the membrane of the tympanum, or

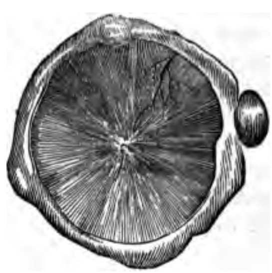
what is better known by the name of the "drum of the ear." The compages of bones consists of four, which are

[This figure represents the bones which form the chain.]

so disposed, and so hinge upon one another, as that if the membrane, the drum of the ear, vibrate, all the four are put in motion together; and, by the result of their action, work the base of that which is the last in the series, upon an aperture which it closes, and upon which it plays, and which aperture opens into the tortuous canals that lead to the brain. This last bone of the four is called the *stapes*. The office of the drum of the ear is to spread out an extended surface, capable of receiving the impressions of sound, and of being put by them into a state of vibration. The office of the stapes is to repeat these vibrations. It is a repeating frigate, stationed more within the line. From which account of its action, may be understood, how the sensation of sound will be excited, by any thing which communicates a vibratory motion to the stapes, though not, as in all ordinary cases, through the intervention of the membrana tympani. This is done by solid bodies applied to the bones of the skull, as by a metal bar holden at one end between the teeth, and touching at the other end a tremulous body. It likewise appears to be done, in a considerable degree, by the air itself, even when this membrane, the drum of the ear, is greatly damaged. Either in the natural or preternatural state of the organ, the use of the chain of bones is to propagate the impulse in a direction towards the brain, and to propagate it with the advantage of a lever; which advantage consists in increasing the force and strength of the vibration, and at the same time diminishing the space through which it oscillates; both of which changes may augment or facilitate the still deeper action of the auditory nerves.

The benefit of the Eustachian tube, to the organ, may be made out upon pneumatic principles. Behind the drum of the ear is a second cavity, or barrel, called the tympanum. The Eustachian tube is a slender pipe, but sufficient for the passage of air, leading from this cavity into the back part of the mouth. Now, it would not have done to have had a vacuum in this cavity; for, in that case, the pressure of the atmosphere from without would have burst the membrane which covered it. Nor would it have done to have filled the cavity with lymph, or any other secretion; which would necessarily have obstructed, both the vibration of the membrane, and the play of the small bones. Nor, lastly, would it have done to have occupied the space with confined air, because the expansion of that air by heat, or its contraction by cold, would have distended or relaxed the covering membrane, in a degree inconsistent with the purpose which it was assigned to execute. The only remaining expedient, and that for which the Eustachian tube serves, is to open to this cavity a communication with the external air. In one word, it exactly answers the purpose of the hole in a drum.

The membrana tympani itself, likewise, deserves all the examination which can be made of it. It is not found in the ears of fish; which furnishes an additional proof, of what indeed is indicated by every thing about it, that it is appropriated to the action of air, or of an elastic medium. It bears an obvious resemblance to the pelt or head of a drum, from which it takes its name. It resembles also a



[This figure represents the membrane of the tympanum *of a larger* size than natural. It is represented as tucked

drum-head in this principal property, that its use depends upon its tension. *Tension* is the state essential to it. Now we know that, in a drum, the pelt is carried over a hoop, and braced as occasion requires, by the means of strings attached to its circumference. In the membrane of the ear, the same purpose is provided for, more simply, but not less mechanically nor less successfully, by a different expedient, viz., by the end of a bone (the handle of the malleus) pressing upon its centre. It is only in very large animals that the texture of this membrane can be discerned. In the Philosophical Transactions, for the year 1800, (vol. i.,) Mr. Everard Home has given some curious observations upon the ear, and the drum of the ear of an *elephant*. He discovered in it what he calls a radiated muscle—that is, straight muscular fibres passing along the membrane from the circumference to the centre—from the bony rim which surrounds it towards the handle of the malleus, to which the central part is attached. This muscle he supposes to be designed to bring the membrane into unison with different sounds; but then he also discovered, that this muscle itself cannot act, unless the membrane be drawn to a stretch, and kept in a due state of tightness, by what may be called a foreign force, viz., the action of the muscles of the malleus. Supposing his explanation of the use of the parts to be just, our author is well founded in the reflection which he makes upon it—" that this mode of adapting the ear to different

in by the handle of the *malleus*. The description of Sir Everard Home, referred to in the text, is altogether fanciful. There is no proof that these fibres are muscular: they are drawn tight by the small muscle attached to the *malleus* called *tensor tympani*; and it would appear that these cords are necessary to produce that variety of motion in the membrane suited to all the variety of sounds which are conveyed through it to the seat of the sense. Sir Everard played to the elephant on the piano-forte. That the animal took some notice of the extraordinary sound cannot surprise us; but the inferences drawn by Sir Everard were equally ingenious and groundless. He supposed that the musical ear was owing to the membrane of the *tympanum*.]

sounds, is one of the most beautiful applications of muscles in the body; *the mechanism is so simple, and the variety of effects so great.*"

In another volume of the Transactions above referred to, and of the same year, two most curious cases are related, of persons who retained the sense of hearing, not in a perfect but in a very considerable degree, notwithstanding the almost total loss of the membrane we have been describing. In one of these cases, the use here assigned to that membrane, of modifying the impressions of sound by change of tension, was attempted to be supplied by straining the muscles of the outward ear. "The external ear," we are told, "had acquired a distinct motion upward and backward, which was observable whenever the patient listened to any thing which he did not distinctly hear; when he was addressed in a whisper, the ear was seen immediately to move; when the tone of voice was louder, it then remained altogether motionless."

It appears probable, from both these cases, that a collateral if not principal use of the membrane is to cover and protect the barrel of the ear which lies behind it. Both the patients suffered from cold: one, "a great increase of deafness from catching cold;" the other, "very considerable pain from exposure to a stream of cold air." Bad effects therefore followed from this cavity being left open to the external air; yet, had the Author of Nature shut it up by any other cover than what was capable, by its texture, of receiving vibrations from sound, and, by its connexion with the interior parts, of transmitting those vibrations to the brain, the use of the organ, so far as we can judge, must have been entirely obstructed.

[REVIEW OF THE USES OF THE PARTS IN THE EAR.

We find late physiological writers acknowledging their ignorance of the functions of the particular structures in this organ: and we cannot therefore conceal that there is a difficulty in assigning the uses of the parts. Nevertheless, we shall now endeavor to explain our conceptions of this matter: and, at all events, there is enough to prove

the main argument of design and of the fine adaptation of this organ to the laws by which sound is propagated.

The outward ear of man and animals is so obviously provided for collecting sound that there can be no cavil here. It is extended and movable in those animals which hear acutely, and in some, as the bat, it is double, consisting of one expanded membrane within the other. And this brings to mind an assertion, that the membrane of the tympanum is affected by the vibrations of the side of the auditory tube more than by the direct impulse of the atmosphere against it; for if there be one conical expanded external ear within another, it is obvious that there must be a larger surface to receive vibrations and communicate them to the tube and membrane of the tympanum.

It suffices with some to say, that the undulation of the sound is received upon the membrane of the tympanum, and by it is communicated to the atmosphere within. But how is the infinite variety of sounds, all, in fact, that we hear, communicated simultaneously through the same membrane? In the first place, the membrane is not simple, nor is it muscular, but contains within it cords or fibres which run from its outer margin, converging towards the malleus. It is now that we look with great interest upon the experiments of Chladni and others on metallic plates. He strews dust upon one of these plates, and then brings out a note by drawing the bow of the violin upon the edge; when the sand, or powder, or dust, will arrange itself in regular figures. These figures are remarkable for their symmetry, dividing the circumference of the plate into equal parts, from six to forty; or the sand divides itself into circles having the same centre with the plate, and the diametrical and circular lines combine to produce an astonishing variety in the configuration of the particles. Here, then, we have a proof that, instead of there being a general undulation or vibration of the whole membrane of the tympanum, it may be subdivided, a motion taking place in its minute parts, and these having many nodes or centres which remain motionless; in short, we perceive a capability of motion in the membrane *corresponding with* the variety of sounds which we know

to be propagated through it. And if we should imagine that the general surface of the membrane was unsuitable for so great a variety of compound motions, the chords visible upon its interior surface may be considered sufficient to allow it to correspond with every possible variety of note. (See the figure, p. 118.)

How satisfactory soever the ingenious experiments in acoustics and with musical instruments may be, there is a difficulty which has not been met in assigning the offices to some of the parts in the ear. The chain of bones in the tympanum undoubtedly communicates the sounds from the membrane of the tympanum to the proper seat of the sense, the labyrinth; and nothing is more easy than to conceive that the membrane of the tympanum, receiving an impulse, like a sail flapping by the wind, should communicate the same to the malleus and in succession to the other bones. But the difficulty arises from considering that it is not a mechanical impulse which is communicated, but a motion of sound. When philosophers teach us the nature of sound by throwing a pebble into a still pond of water and making us observe the concentric undulations: or by striking a chord and observing the motions which accompany the sound, and showing the harmonic subdivisions, we seem to have overcome all the difficulties of the science. But we encounter new difficulties when we are forced to conclude, that all the combinations of sound in an orchestra, for example, are transmitted through a chain of bones, some of which are not greater in diameter than a horse-hair. We are reminded that the undulations visible to the eye, or felt by the finger, are not the motions of sound, although they accompany them, and that they must be of a nature much more minute and delicate. There is no instance of one organ of sense conveying the knowledge of a quality of matter for the perception of which another organ is provided. Still, perhaps, these microscopic observations may assist our invention. When a powerful lens is applied to a metallic chord sounding, and we distinguish the brilliant particles on its surface, those particles have not the motions merely to and fro, which are caused by the division and subdivision of the

elastic chord: those brilliant particles dance in figures infinitely varied, combined of circles and angles which it is perhaps impossible to describe and reduce to any system. Such facts aid us in comprehending how different motions of sound may be communicated at the same moment.

It is ascertained that if a metallic rod be placed in contact with a sounding-board, to which the sounds of many instruments playing in concert are communicated, and if that rod be extended to a great length, or if it be carried through a partition, so that we are out of ear-shot of the instruments, and if the rod communicate at its further end with another sounding-board, the motions of that board will be given out to the atmosphere, and we shall hear the concert, that is, the combined sounds of the instruments, although necessarily faint. Here, then, the music must have been conveyed along the rod; and we have another proof that sound cannot consist of those coarser movements ascertained by the other senses, but of something so infinitely more minute that the particles in the rod may convey distinct vibrations simultaneously. These considerations certainly countenance our belief, that however fine the chain of bones may be which, passing through the tympanum, communicates between the external and internal ear, it is yet capable of a variety of motions corresponding with the sounds, of which the ear is susceptible.

What, then, is the meaning of this very obvious mechanical structure in the chain of bones in these little levers and their attached muscles? (See the figure, p. 116.) Are not the three muscles, attached to the bone that is fixed to the membrane, calculated to affect the tension of the membrane? If we take the illustration in the text, we must remember that the military drum is not so simple as it has been represented. The chords or braces, which pass outside the drum obliquely, are tightened by pushing down the knots of buff leather, and this not only stretches the parchment head of the drum, but tightens the snares or cords which run over the parchment of the reverse of the drum. In the military drum, it is the blow on the parchment that gives the loud and sudden sound; *while the chords alter* and prolong the sound. The three

muscles which are attached to the malleus, and through it to the membrane of the tympanum, we must suppose may either brace or throw loose the membrane and its chords, as the drum is braced or muffled: and in this way, the small muscles of the tympanum may have a resemblance in function to the fibres of the iris; they may guard the nerve of hearing as the latter does the nerve of vision. We had occasion to observe, that when a person is deaf from the disorder of this apparatus, and when he substitutes the ear-trumpet, he may hear; for the ear-trumpet, by its expanded mouth, collects the undulations of sound and concentrates them; but there is this imperfection, that the ear wants its power of adjustment; and the person is accordingly often timid in the use of his instrument with those who are not accustomed to speak to him, the sound of some voices being painfully harsh. Further, we may not hear a sound when called upon to listen to it, and yet, when the particular sound is described, we do hear it; now it remains to be determined whether this be a power of adjustment in the ear, or owing to the effect of association in the mind.

It is supposed by some that there are two tracts, by which sound is communicated to the labyrinth; that it passes both through the chain of bones and through the air in the tympanum. With regard to the last mode, I can conceive no cavity less suited to convey sounds. Instead of having a definite form like the tube of the ear, by which the vibrations might be received and directed inwards, the tympanum opens into the cells of the temporal bone, and presents the most irregular surface possible, and such as would inevitably break and destroy any regular sound. The extension of cavity of the tympanum is calculated to increase the elasticity of the air in the tympanum, but most certainly not to collect or to strengthen the sound.

With regard to the labyrinth, comparative anatomy lends us considerable assistance. Were vibrations of sound being communicated to the brain the cause of hearing, the brain itself would be the organ, and no special nerve necessary. The brain in some animals, being placed *in a cavity*, and surrounded with fluid, is subjected neces-

sarily to vibration. But we perceive that, in addition, an appropriate nerve and distinct organ are bestowed. There is in the cuttle-fish, very little apparatus in this organ, and it proves that the essential part of the ear is the nerve susceptible of sound, and not the exterior apparatus. Some sixty years ago, learned men in Italy wished to ascertain whether the lobster had the organ of hearing, or not. The celebrated Professor Scarpa, then a young man, undertook to decide that matter; not by looking for the exterior organ, but by examining the brain and the nerves which go out from it. Finding that there was a nerve which stood in the relation of an acoustic nerve, he traced it onward and found it terminating in a little sac containing fluid, and open to the influence of the atmosphere by a small membrane which crossed the mouth of it. This was the just and philosophical mode of proceeding. There being, in fact, nothing in the brain itself, with respect to its exposure to tremors or motion, different from the auditory nerve, if that nerve had had merely to convey a vibration to the brain, it would have been superfluous, as the brain itself would have vibrated. Hence we perceive that an endowment of a nerve which shall be susceptible of the sense of sound is necessary, and consequently it is the primary and essential part of the organization. How the motions of sound shall reach it, is another question.

Let us now carry along with us the fact, that solids and fluids are much better vehicles of sound than the atmosphere; that it is the rarity and elasticity of the atmosphere which makes all that exterior apparatus, which we have been considering, necessary. Accordingly, an exterior ear is not wanted in the fish. If a man dive under water and carry a stone in each hand and strike the stones together, he is sensible of a stunning sound, and indeed of an impression on the whole surface of his body. In short, although it was once doubted whether water were capable of propagating sound, a hundred instances can now be brought forward to prove that it can receive or propagate every degree of sound and tone. Again, when we find *that the solid parts* of the head convey sounds, we per-

ceive that in the fish there is no occasion even for an external opening, far less an external ear. An apparatus of a totally different kind is bestowed. Within a little sac of fluid, a bone or concretion is suspended, which, being more solid than the surrounding fluid, receives the vibration, and moves, necessarily producing waves or motion in the surrounding fluid, and consequently an agitation of the extremities of the nerves exposed to the fluid. A very simple but curious experiment of Professor Camper illustrates the effect of this structure : A bladder containing a marble and full of water being held in the hand, the slightest motion of the hand was attended with a vibration communicated from the water to the hand ; the effect of the motion of the marble upon the surrounding water.

With respect to the semicircular canals above described, I am at a loss to understand what is meant by some authors saying that their use is not known. These canals consist of an elastic membrane, full of fluid, with a nerve suspended upon the septum of one extremity : are they not, then, admirably suited to receive the impulses which are conveyed through the bones of the head? That they are so, is clear from their being found in the heads of fishes, where there is no access of vibration to the nerve except through the bone. But we are affected by the same when our head is on the pillow and we are awakened by people moving in the house : the alarm is through the solid bones of the head. And when the Indian puts his ear to the ground to hear a distant tread, he is substituting the communication through the solids and the bones of the head for the atmospheric impulses.

Again, let us recur to the proposition that sound is propagated to the internal ear in two ways : through the chain of bones and fenestra ovalis into the vestibule, and also through the air of the tympanum, and by the fenestra rotunda into the cochlea. There appear strong objections to this doctrine. It declares the chain of bones and their appended muscles and beautiful articulations to be altogether useless : for if the sound can be communicated through the air of the tympanum, what is the meaning of this complex apparatus ? And if the bones of the

ear communicate better, what is the use of the vibration coming by any other course? Let us understand, then, that the whole exterior apparatus—that is to say, the parts exterior to the labyrinth—are necessary only to perfect hearing, and that when they are all gone by disease, those essential parts of the organ which we see suffice in the lower animals, continue to receive sounds.

The apparatus of bones and muscles, connected with the membrane of the tympanum, (see pages 116, 117,) is of more consequence, than physiologists allow. It is essential to perfect hearing, even when the sound is conveyed through the solid bones. If we hold a watch between the teeth, the sound is propagated through the solid parts; but let us compress and close the outer tube of one of the ears, and the sound will be increased on that side. If a person, being deaf in one ear, put his watch close to that ear, he will not hear the ticking; but, if at the same time he presses on the tube of the other ear and closes it, he will then hear the ticking on that side. It appears that in this experiment, the sound propagated through the bones is not given directly to the nerve, but to the membrane and bones of the tympanum, and through them back upon the nerve. The air in the outer tube of the ear, being pent up by the pressure of the fingers and compressed, receives the vibration, reverberates on the membrane of the tympanum, and puts the apparatus within the tympanum into play.

Drawing a fair inference from the demonstration, it would appear, that the impulses upon the membrane of the tympanum are communicated to the membrane of the fenestra ovalis, and that the opening called the fenestra rotunda, closed by a similar membrane, is for the purpose not of receiving impulse from without but of yielding to that impulse from within. For example, if we suppose a bottle of water full to the lip, and a bladder drawn over it so that not a bubble of air is contained, although that water must be admitted to be compressible, an impulse over the bladder would produce no such effect as would follow were there a hole covered with a bladder upon the side or bottom of the bottle; for then each

impulse upon the top would be attended with a yielding of the bladder below, and a consequent agitation in all the intermediate fluid. Thus, it appears to us that the use of the fenestra rotunda and its membrane is to give play to the membrane of the fenestra ovalis, and that, without this provision, although there might be a general impulse communicated to the fluid in the labyrinth, like that communicated through the bones generally, there could be no wave or undulation. If the shutting of the Eustachian tube, (D, page 115,) so confines the *air* in the large cavity of the tympanum, as to render us deaf, what would be the consequence of the labyrinth (which contains *water*) being shut in on every side? The play, then, of the bones of the tympanum, and of the membrane of the fenestra ovalis and of the fenestra rotunda, is not only required to produce an undulation in the fluid within the labyrinth, but that undulation must take the particular course through the scala of the cochlea, descending into it by the scala vestibuli and ascending by the scala tympani. (See F, page 115.) In this view it becomes interesting to consider the distribution of the nerve in the cochlea, since this internal part of the organ is so obviously connected with the finer exterior apparatus. We have learned that the nerve passes into the modiolus and extends to the edge of the lamina spiralis, so that the sonorous undulations continued through these passages must affect the nerve on two surfaces; and whether we consider the cochlea to be like the bending of the spiral turns of a wind instrument, or the fibres of the lamina spiralis to be like a succession of chords diminishing regularly in length, we can at least imagine that at one time the whole portion of the nerve may be brushed and agitated, and that at another it may be partially affected.

In short, the concavities of the central cavity of the labyrinth, the vestibule, may produce an eddying of the fluid, so that the motion shall be concentrated to a point, on which point there is seated a portion of the nerve; or the undulation may pass round the semicircular canals, and affect the septum of each ampulla; or, by being propagated through the cochlea, it may touch fibres of

the lamina spiralis of different lengths. All we mean to affirm, is, that there is so great an extent and variety in the distribution of the acoustic nerve, and also in the canals and cavities, as fairly to give us reason for believing them to be the sources of that extensive scale, and of all the changes and combinations of sound which we enjoy through this sense.—SIR CHARLES BELL.]

CHAPTER IV.

ON THE SUCCESSION OF PLANTS AND ANIMALS.

THE *generation* of the animal no more accounts for the contrivance of the eye or ear, than, upon the supposition stated in a preceding chapter, the production of a watch, by the motion and mechanism of a former watch, would account for the skill and attention evidenced in the watch so produced; than it would account for the disposition of the wheels, the catching of their teeth, the relation of the several parts of the works to one another, and to their common end; for the suitableness of their forms and places to their offices; for their connexion, their operation, and the useful result of that operation. I do insist most strenuously upon the correctness of this comparison; that it holds as to every mode of specific propagation; and that whatever was true of the watch, under the hypothesis above-mentioned, is true of plants and animals.

I. To begin with the fructification of plants. Can it be doubted but that the seed contains a particular organization? Whether a latent plantule, with the means of temporary nutrition, or whatever else it be, it encloses an organization suited to the germination of a new plant. Has the plant which produced the seed any thing more to do with that organization, than the watch would have had to do with the structure of the watch which was produced in the course of its mechanical movement? I mean, Has it any thing at all to do with the contrivance? *The maker and* contriver of one watch, when he inserted

within it a mechanism suited to the production of another watch, was, in truth, the maker and contriver of that other watch. All the properties of the new watch, were to be referred to his agency: the design manifested in it, to his intention: the art, to him as the artist: the collocation of each part, to his placing: the action, effect, and use, to his counsel, intelligence, and workmanship. In producing it by the intervention of a former watch, he was only working by one set of tools instead of another. So it is with the plant, and the seed produced by it. Can any distinction be assigned between the two cases; between the producing watch, and the producing plant; both passive unconscious substances; both, by the organization which was given to them, producing their like, without understanding or design; both, that is, instruments?

II. From plants we may proceed to oviparous animals: from seeds to eggs. Now, I say, that the bird has the same concern in the formation of the egg which she lays, as the plant has in that of the seed which it drops; and no other nor greater. The internal constitution of the egg is as much a secret to the hen as if the hen were inanimate. Her will cannot alter it, or change a single feather of the chick. She can neither foresee nor determine of which sex her brood shall be, or how many of either; yet the thing produced shall be, from the first, very different in its make according to the sex which it bears. So far, therefore, from adapting the means, she is not beforehand apprized of the effect. If there be concealed within that smooth shell a provision and a preparation for the production and nourishment of a new animal, they are not of her providing or preparing; if there be contrivance, it is none of hers. Although, therefore, there be the difference of life and perceptivity between the animal and plant, it is a difference which enters not into the account: it is a foreign circumstance: it is a difference of properties not employed. The animal function and the vegetable function are alike destitute of any design which can operate upon the form of the thing produced. The plant has no design in producing *the seed;* no comprehension of the nature or use of what

it produces: the bird, with respect to its egg, is not above the plant with respect to its seed. Neither the one nor the other bears that sort of relation to what proceeds from them which a joiner does to the chair which he makes. Now, a cause which bears *this* relation to the effect, is what we want, in order to account for the suitableness of means to an end—the fitness and fitting of one thing to another; and this cause, the parent plant or animal does not supply.

It is further observable, concerning the propagation of plants and animals, that the apparatus employed exhibits no resemblance to the thing produced; in this respect, holding an analogy with instruments and tools of art. The filaments, antheræ, and stigmata of flowers, bear no more resemblance to the young plant, or even to the seed which is formed by their intervention, than a chisel or a plane does to a table or chair. What, then, are the filaments, antheræ, and stigmata, of plants, but instruments, strictly so called?

III. We may advance from animals which bring forth eggs, to animals which bring forth their young alive; and, of this latter class, from the lowest to the highest; from irrational to rational life, from brutes to the human species; without perceiving, as we proceed, any alteration whatever in the terms of the comparison. The rational animal does not produce its offspring with more certainty or success than the irrational animal: a man than a quadruped, a quadruped than a bird; nor (for we may follow the gradation through its whole scale) a bird than a plant; nor a plant than a watch, a piece of dead mechanism, would do, upon the supposition which has already so often been repeated. Rationality, therefore, has nothing to do in the business. If an account must be given of the contrivance which we observe; if it be demanded, whence arose either the contrivance by which the young animal is produced, or the contrivance manifested in the young animal itself, it is not from the reason of the parent, that any such account can be drawn. He is the cause of his offspring, in the same sense as that in which a gardener is the cause of the tulip which grows upon his parterre, *and in no other*. We admire the flower; we examine

the plant; we perceive the conduciveness of many of its parts to their end and office: we observe a provision for its nourishment, growth, protection, and fecundity; but we never think of the gardener in all this. We attribute nothing of this to his agency; yet it may still be true, that without the gardener we should not have had the tulip. Just so it is with the succession of animals, even of the highest order. For the contrivance discovered in the structure of the thing produced, we want a contriver. The parent is not that contriver: his consciousness decides that question. He is in total ignorance why that which is produced took its present form rather than any other. It is for him only to be astonished by the effect. We can no more look, therefore, to the intelligence of the parent animal, for what we are in search of—a cause of relation, and of subserviency of parts to their use, which relation and subserviency we see in the procreated body—than we can refer the internal conformation of an acorn to the intelligence of the oak from which it dropped, or the structure of the watch to the intelligence of the watch which produced it; there being no difference, as far as argument is concerned, between an intelligence which is not exerted, and an intelligence which does not exist.[8]

[8] When we have, in some measure, comprehended the system of an animal body, how the different organs are related to each other, and how the whole exists through a mutual influence of its parts, the wonder is renewed how another creature should grow out of that, which, as far as we have seen, has no tendency to multiply itself. Authors who treat of reproduction, even to the very last, affirm, that, with the germ of life, in all organized structures, are conjoined the seeds of decay and of death: they tell us that the powers of life are finite, and that the time must come when they shall be expended. Now there are no seeds of decay; and although, according to the law of animal existence, the individual perishes, it is incorrect to say that it is the result of the exhaustion of the powers of vitality, or the deterioration of the material which enters into its composition. We gain nothing by adapting the language of one science to explain another; it is of no advantage, in treating of life and death, to adopt a chemical nomenclature. The term of life in every creature, from the elephant to the ephemeral fly, has its limit; but it is wrong to say that it is by the defect of the material, or of the energy of life: it is a better philosophy to admit that it is in accordance with the system which the *Deity has* ordained.

Life, in the sense in which it is used here, is continued in the germ

CHAPTER V.

APPLICATION OF THE ARGUMENT, CONTINUED.

EVERY observation, which was made in our first chapter, concerning the watch, may be repeated with strict

that rises from the parent; since out of the old body, that is described as a deteriorated and useless material, a new creation is produced, it suffices to show that there is no necessary decay from the material itself. A leaf or twig of an old tree will strike root into the ground, and vegetate and exhibit youthful vigor. So will the fresh-water polypus furnish a portion which, being cut off, will grow with a perfect resemblance to the original stock. In the reproduction of the higher and the more complex organized bodies, there is much that is obscure; but in the simpler, and, as it is termed, the lower examples—vegetables, zoophytes, and infusory animals—we have abundant proofs that the result does not proceed from the exhausted or deteriorated nature of the material.

Amongst the infusora, the animals called *Monads*, of which there is a great variety, exhibit very curious phenomena. They are of a globular form, and this globe is seen first to contract, and then divide, each becoming a distinct animal. And something like this, may be done artificially, by the division of the fresh-water polypus, or hydra; and what is deficient in the divided portion, is supplied by a new growth, be it head or tail. The thing, however, is not so remarkable, if we consider that those lower animals have abundant resemblance to vegetables; and that, in cutting off portions, the experimenter is cutting off buds. These buds or tubercles, if left to undergo their natural changes, acquire independent motion, produce tentacula, or feelers, to procure food, and, thus prepared to be independent, fall off from the parent stock.

The microscope exhibits another instance in the *Volvox*. It is a transparent globule, within which smaller globules may be seen; and when matured, the parent bursts, discloses the offspring, and dies.

In all these examples, we see that there is no reason to speak of exhausted or deteriorated matter, or debility in the powers of life.

So in the higher and the more complex animals, we find one set of organs decaying, and another rising into existence. Contemplating the one, we would say that the powers were decaying; contemplating the other, that they were fresh and vigorous. We must come to the conclusion, then, that the growth of parts, or the period of their developement, the decay of the animal, or of the parts of the animal, is by an ordinance which is very inaccurately expressed by the terms, exhaustion of life, or imperfection of the material. Imperfection, in truth, is a relative term, and means failure or insufficiency towards *the accomplishment* of certain purposes. If the object in view were

propriety concerning the eye; concerning animals; concerning plants; concerning, indeed, all the organized parts of the works of Nature. As,

I. When we are inquiring simply after the *existence* of an intelligent Creator, imperfection, inaccuracy, liability to disorder, occasional irregularities, may subsist in a considerable degree, without inducing any doubt into the question: just as a watch may frequently go wrong, seldom perhaps exactly right, may be faulty in some parts, defective in some, without the smallest ground of suspicion from thence arising that it was not a watch, not made, or not made for the purpose ascribed to it. When faults are pointed out, and when a question is started concerning the skill of the artist, or dexterity with which the work is executed, then, indeed, in order to defend these qualities from accusation, we must be able, either to expose some intractableness and imperfection in the materials, or point out some invincible difficulty in the execution, into which imperfection and difficulty the matter of complaint may be resolved; or, if we cannot do this, we must adduce such specimens of consummate art and contrivance, proceeding from the same hand, as may convince the inquirer of the existence, in the case before him, of impediments, like those which we have mentioned, although, what from the nature of the case is very likely to happen, they be unknown and unperceived by him. This we must do, in order to vindicate the artist's skill, or at least the perfection of it; as we must also judge of his intention, and of the provisions employed in fulfilling that intention, not from an instance in which they fail, but from the great plurality of instances in which they succeed. But, after all, these are different questions from the question of the artist's existence; or, which is the same, whether the thing before us be a work of art or not; and the questions ought always to be kept separate in the mind. So, likewise, it is in the works of Nature. Irregularities and imperfections are of little or no weight

the duration of animal bodies for a great length of time, we might be justified in saying that the materials they are made of are imperfect; but *this is* clearly not the design with which they are formed.—ENG. ED.

in the consideration, when that consideration relates simply to the existence of a Creator. When the argument respects his attributes, they are of weight; but are then to be taken in conjunction (the attention is not to rest upon them, but they are to be taken in conjunction) with the unexceptionable evidences which we possess of skill, power, and benevolence, displayed in other instances; which evidences may, in strength, number, and variety, be such, and may so overpower apparent blemishes, as to induce us, upon the most reasonable ground, to believe that these last ought to be referred to some cause, though we be ignorant of it, other than defect of knowledge or of benevolence in the author.

II. There may be also parts of plants and animals, as there were supposed to be of the watch, of which, in some instances, the operation, in others, the use, is unknown. These form different cases; for the operation may be unknown, yet the use be certain. Thus it is with the lungs of animals. It does not, I think, appear, that we are acquainted with the action of the air upon the blood, or in what manner that action is communicated by the lungs; yet we find that a very short suspension of their office destroys the life of the animal.[9] In this case, therefore, we may be said to know the use, nay, we experience the necessity, of the organ, though we be ignorant of its operation. Nearly the same thing may be observed of what is called the lymphatic system. We suffer grievous inconveniences from its disorder, without being informed of the office which it sustains in the economy of our bodies. There may, possibly, also be some few examples of the second class, in which not only the operation is unknown, but in which experiments may seem to prove that the part is not necessary; or may leave a doubt how far it is even useful, to the plant or animal in which it is found. This

[9] Undoubtedly the exposure of the blood to the atmosphere, in the circulation through the lungs, and the throwing off of carbon, are essential to life. But the pain and alarm excited when there is danger of suffocation are not so much a direct consequence of the interruption of the function, as an instance of the manner in which the sensibility is bestowed *to guard the important* actions of life.—Eng. Ed.

is said to be the case with the spleen, which has been extracted from dogs without any sensible injury to their vital functions. Instances of the former kind, namely, in which we cannot explain the operation, may be numerous; for they will be so in proportion to our ignorance. They will be more or fewer to different persons, and in different stages of science. Every improvement of knowledge diminishes their number. There is hardly, perhaps, a year passes, that does not, in the works of Nature, bring some operation, or some mode of operation, to light, which was before undiscovered—probably unsuspected. Instances of the second kind, namely, where the part appears to be totally useless, I believe to be extremely rare; compared with the number of those of which the use is evident, they are beneath any assignable proportion, and perhaps have been never submitted to a trial and examination sufficiently accurate, long enough continued, or often enough repeated. No accounts which I have seen are satisfactory. The mutilated animal may live and grow fat, (as was the case of the dog deprived of its spleen,) yet may be defective in some other of its functions, which, whether they can all, or in what degree of vigor and perfection, be performed, or how long preserved without the extirpated organ, does not seem to be ascertained by experiment. But to this case, even were it fully made out, may be applied the consideration which we suggested concerning the watch, viz., that these superfluous parts do not negative the reasoning which we instituted concerning those parts which are useful, and of which we know the use; the indication of contrivance with respect to them, remains as it was before.[10]

[10] In the higher animals there is a great complication of organs. Yet, in the lower animals, the functions of digestion, respiration, assimilation, secretion, and growth proceed by means of an apparatus comparatively simple. We must not be surprised, then, that certain parts may be removed from the higher animals without destroying life. But this does not imply that those parts are useless, since they are structures superadded for the finer adjustment of the different functions one to the other, belonging to a higher condition of the economy.

With regard to parts which are thus called useless, we must remember that the varieties of created animals belong to one type. As we have just said, the essential functions are the same in all; and there is much

III. One atheistic way of replying to our observations upon the works of Nature, and to the proofs of a Deity which we think that we perceive in them, is to tell us, that all which we see must necessarily have had some form, and that it might as well be its present form as any other. Let us now apply this answer to the eye, as we did before to the watch. Something or other must have occupied that place in the animal's head; must have filled up, we will say, that socket: we will say, also, that it must have been of that sort of substance which we call animal substance, as flesh, bone, membrane, or cartilage, &c. But that it should have been an *eye*, knowing as we do what an eye comprehends, viz., that it should have consisted, first, of a series of transparent lenses (very different, by the by, even in their substance, from the opaque materials of which the rest of the body is, in general at least, composed; and with which the whole of its surface, this single portion of it excepted, is covered:) secondly, of a black cloth or canvass (the only membrane of the body which is black) spread out behind these lenses, so as to receive the image formed by pencils of light transmitted through them; and placed at the precise geometrical distance, at which, and at which alone, a distinct image could be formed, namely, at the concourse of the refracted rays: thirdly, of a large nerve communicating between this membrane and the brain; without which, the action of light upon the membrane, however modified by the organ, would be lost to the purposes of sensation:—that this fortunate conformation of parts should have been the lot, not of one individual out of many thousand individuals, like the great prize in the lottery, or like some singularity in nature, but the happy chance of a whole species: nor of one species out of many thousand species, with which we are acquainted, but of by far the greatest number of all that exist; and that under varieties, not

of the structure common to all: when an animal of a particular class has its organization adjusted to a certain condition of existence, we may see the rudiments of parts which, not being in action, are imperfect, and *we must look to the individuals of another species or variety to discover them in their full developement.*—Eng. Ed.

casual or capricious, but bearing marks of being suited to their respective exigences:—that all this should have taken place, merely because something must have occupied these points on every animal's forehead; or, that all this should be thought to be accounted for by the short answer, that "whatever was there must have had some form or other," is too absurd to be made more so by any argumentation. We are not contented with this answer; we find no satisfaction in it, by way of accounting for appearances of organization, far short of those of the eye, such as we observe in fossil shells, petrified bones, or other substances which bear the vestiges of animal or vegetable recrements, but which, either in respect to utility, or of the situation in which they are discovered, may seem accidental enough. It is no way of accounting even for these things, to say, that the stone, for instance, which is shown to us, (supposing the question to be concerning a petrifaction,) must have contained some internal conformation or other. Nor does it mend the answer to add, with respect to the singularity of the conformation, that, after the event, it is no longer to be computed what the chances were against it. This is always to be computed when the question is, whether a useful or imitative conformation be the produce of chance or not: I desire no greater certainty in reasoning than that by which chance is excluded from the present disposition of the natural world. Universal experience is against it. What does chance ever do for us? In the human body, for instance, chance, *i. e.*, the operation of causes without design, may produce a wen, a wart, a mole, a pimple, but never an eye. Amongst inanimate substances, a clod, a pebble, a liquid drop might be; but never was a watch, a telescope, an organized body of any kind, answering a valuable purpose by a complicated mechanism, the effect of chance.[11] In no assignable instance hath such a thing existed without intention somewhere.

[11] There is a great inaccuracy, and indeed a very unphilosophical and superficial view of the subject in these observations upon *chance*. *Chance is* merely an abridged form of expressing our ignorance of *the cause* or preceding event to which any given event may be traced; *and nothing* can be more inaccurate, or indeed more productive of

IV. There is another answer which has the same effect as the resolving of things into chance; which answer would persuade us to believe, that the eye, the animal to which it belongs, every other animal, every plant, indeed every organized body which we see, are only so many out of the possible varieties and combinations of being which the lapse of infinite ages has brought into existence; that the present world is the relic of that variety; millions of other bodily forms and other species having perished, being, by the defect of their constitution, incapable of preservation, or of continuance by generation. Now there is no foundation whatever for this conjecture in any thing which we observe in the works of Nature; no such experiments are going on at present; no such energy operates as that which is here supposed, and which should be

serious errors in this very branch of science, than to speak of chance, as a substantive thing or power. To take the most obvious instance: we say, in common parlance, that the dice being shaken together, it is a matter of chance what faces they will turn up; but if we could accurately observe their position in the box before the shaking, the direction of the force applied, its quantity, the number of turns of the box, and the curve in which the motion was made, the manner of stopping the motion, and the line in which the dice were thrown out, the faces turned up would be a matter of certain prediction, after a sufficient number of experiments had been made to correct the theory. It is only because we take no heed of all these things, that we are ignorant what will be the event; and the darkness in which we are, respecting the circumstances which regulate it, is called by the name of chance. Nor is it correct to say, that this or any thing else is done without design. All we can mean by the expression is, that our design stops short at a certain point, and leaves the laws of Nature to guide the rest of the operation. But such a position is manifestly quite inapplicable to the operations of Nature.

Equally inaccurate is it, if not more so, to speak of a wen or a pimple, &c., as the result of any cause in the least degree different from that which produced the eye. These are possibly always, certainly sometimes, diseases; but they are the result of contrivance as clearly as the eye itself. The functions of the animal system, though acting in an unusual manner, yet acting according to rule, produce those phenomena. Indeed one of them, a pimple, is, in part at least, the result of the provision made for restoring the interrupted continuity of the skin, by a slight suppuration from which the granulation, or production of new animal fibre, takes place. The like remark applies to the cases of a clod, a pebble, or liquid drop, also put in this passage. We have already adverted to the first two, in a former note; the *formation of a drop, is,* in truth, one of the phenomena of *gravitation, and a very remarkable* one.—ENG. ED.

constantly pushing into existence new varieties of beings. Nor are there any appearances to support an opinion, that every possible combination of vegetable or animal structure has formerly been tried. Multitudes of conformations, both of vegetables and animals, may be conceived capable of existence and succession, which yet do not exist. Perhaps almost as many forms of plants might have been found in the fields as figures of plants can be delineated upon paper. A countless variety of animals might have existed which do not exist. Upon the supposition here stated, we should see unicorns and mermaids, sylphs and centaurs, the fancies of painters, and the fables of poets, realized by examples. Or, if it be alleged that these may transgress the bounds of possible life and propagation, we might at least have nations of human beings without nails upon their fingers, with more or fewer fingers and toes than ten, some with one eye, others with one ear, with one nostril, or without the sense of smelling at all. All these, and a thousand other imaginable varieties, might live and propagate. We may modify any one species many different ways, all consistent with life, and with the actions necessary to preservation, although affording different degrees of conveniency and enjoyment to the animal. And if we carry these modifications through the different species which are known to subsist, their number would be incalculable. No reason can be given why, if these deperdits* ever existed, they have now disappeared. Yet, if all possible existences have been tried, they must have formed part of the catalogue.[12]

[* Things which are lost or destroyed.—AM. ED.]

[12] No doubt men in different ages have asserted the possibility of all we see being made by chance; but we are not uncharitable when we say, that no man ever believed it. It is easily shown, that, of all the varieties of fabulous animals which have been bred in the fertile imagination of the poet, not one could have lived. They want that relation and balance of the different organs, that provision running through the whole texture of the frame of the animal, which we see in the natural productions. The sphinx has wings, but no constitution of body to give these strength. The griffin, with its hooked bill, has no feathers to prin, and no substitute for teeth. The centaur has the body of a horse, but no mouth to gather appropriate food.

But, moreover, the division of organized substances into animals and vegetables, and the distribution and sub-distribution of each into genera and species, which distribution is not an arbitrary act of the mind, but founded in the order which prevails in external nature, appear to me to contradict the supposition of the present world being the remains of an indefinite variety of existences ; of a variety which rejects all plan. The hypothesis teaches, that every possible variety of being hath, at one time or other, found its way into existence, (by what cause or in what manner is not said,) and that those which were badly formed perished ; but how or why those which survived should be cast, as we see that plants and animals are cast, into regular classes, the hypothesis does not explain ; or rather the hypothesis is inconsistent with this phenomenon.

The hypothesis, indeed, is hardly deserving of the consideration which we have given to it. What should we think of a man who, because we had never ourselves seen watches, telescopes, stocking-mills, steam-engines, &c. made, knew not how they were made, nor could prove by testimony when they were made, or by whom, would have us believe that these machines, instead of deriving their curious structure from the thought and design of their inventors and contrivers, in truth derive them from no other origin than this : viz., that a mass of metals and other materials having run, when melted, into all possible figures, and combined themselves in all possible forms, and shapes, and proportions, these things which we see are what were left from the accident, as best worth preserving, and, as such, are become the remaining stock of a magazine, which, at one time or other, has by this means contained every mechanism, useful and useless, convenient

We may conclude then, that these products of the imagination are altogether abortive, and only tend to prove how exact the relation must be of all the parts, and especially of the vital organs of an animal, in order that it may live.

As to the second position, that the animals which exist are the happy results of chance when thousands have perished by imperfection, the supposition is contradicted by the perfect and harmonious chain of beings forming the animal kingdom, in which there is no link *interrupted, no interval,* implying the loss of any species.—Eng. Ed.

and inconvenient, into which such like materials could be thrown? I cannot distinguish the hypothesis, as applied to the works of Nature, from this solution, which no one would accept, as applied to a collection of machines.

V. To the marks of contrivance discoverable in animal bodies, and to the argument deduced from them in proof of design and of a designing Creator, this turn is sometimes attempted to be given, namely, that the parts were not intended for the use, but that the use arose out of the parts. This distinction is intelligible. A cabinet-maker rubs his mahogany with fish-skin; yet it would be too much to assert that the skin of the dog-fish was made rough and granulated on purpose for the polishing of wood, and the use of cabinet-makers. Therefore the distinction is intelligible. But I think that there is very little place for it in the works of Nature. When roundly and generally affirmed of them, as it hath sometimes been, it amounts to such another stretch of assertion, as it would be to say, that all the implements of the cabinet-maker's workshop, as well as his fish-skin, were substances accidentally configurated, which he had picked up and converted to his use; that his adzes, saws, planes, and gimlets, were not made, as we suppose, to hew, cut, smooth, shape out, or bore wood with; but that, these things being made, no matter with what design, or whether with any, the cabinet-maker perceived that they were applicable to his purpose, and turned them to account.

But, again. So far as this solution is attempted to be applied to those parts of animals, the action of which does not depend upon the will of the animal, it is fraught with still more evident absurdity. Is it possible to believe that the eye was formed without any regard to vision; that it was the animal itself which found out that, though formed with no such intention, it would serve to see with; and that
se of the eye as an organ of sight resulted from this
ery, and the animal's application of it? The same
n may be asked of the ear; the same of all the sen-
one of the senses fundamentally depend upon the
of the animal; consequently, neither upon his sa-
or his experience. It is the impression which ob-

jects makes upon them that constitutes their use. Under that impression he is passive. He may bring objects to the sense, or within its reach; he may select these objects; but over the impression itself he has no power, or very little; and that properly is the sense.

Secondly; there are many parts of animal bodies which seem to depend upon the will of the animal in a greater degree than the senses do, and yet with respect to which this solution is equally unsatisfactory. If we apply the solution to the human body, for instance, it forms itself into questions upon which no reasonable mind can doubt; such as, whether the teeth were made expressly for the mastication of food, the feet for walking, the hands for holding? or whether, these things being as they are, being in fact in the animal's possession, his own ingenuity taught him that they were convertible to these purposes, though no such purposes were contemplated in their formation?

All that there is of the appearance of reason in this way of considering the subject, is, that, in some cases, the organization seems to determine the habits of the animal, and its choice to a particular mode of life; which, in a certain sense, may be called "the use arising out of the part."[13] Now, to all the instances in which there is any place for this suggestion, it may be replied, that the organization determines the animal to habits beneficial and salutary to itself; and that this effect would not be seen so regularly to

[13] We deceive ourselves in this matter: the dexterity which use gives, makes us apt to believe that the faculty is gained through the accidental possession of the instrument. But the difficulty is removed, if we make due comparison between man and other animals. In the former, it is intended that the faculty should be gradually developed; and the slowness with which perfection is attained leaves us in some doubt of the relation between the effort and the instrument used. But in the latter, all obscurity is removed: their propensities and instincts, and the use of their instruments, are so perfect from the beginning, as to admit of no improvement. The fly-catcher requires no experience to adjust his eye, no second effort of his bill to correct the first. Whether it be the horn, or the tooth, or the sting, the disposition is given with it, and the mode of its action is prescribed. The spider weaves his web without improvement, or room for improvement. This subject is treated at some length in the 'Bridgewater Treatise on the Hand,' where the question is discussed, whether or not the possession of the hand is the source *of man's superiority.*—Eng. Ed.

follow, if the several organizations did not bear a concerted and contrived relation to the substance by which the animal was surrounded. They would, otherwise, be capacities without objects; powers without employment. The web-foot determines, you say, the duck to swim; but what would that avail, if there were no water to swim in? The strong hooked bill and sharp talons of one species of bird determine it to prey upon animals; the soft straight bill and weak claws of another species determine it to pick up seeds: but neither determination could take effect in providing for the sustenance of the birds, if animal bodies and vegetable seeds did not lie within their reach. The peculiar conformation of the bill and tongue and claws of the woodpecker determines that bird to search for his food amongst the insects lodged behind the bark or in the wood of decayed trees; but what would this profit him if there were no decayed trees, no insects lodged under their bark, or in their trunk? The proboscis with which the bee is furnished determines him to seek for honey: but what would that signify, if flowers supplied none? Faculties thrown down upon animals at random, and without reference to the objects amidst which they are placed, would not produce to them the services and benefits which we see: and if there be that reference, then there is intention.

Lastly; the solution fails, entirely, when applied to plants. The parts of plants answer their uses without any concurrence from the will or choice of the plant.

VI. Others have chosen to refer every thing to a *principle of order* in Nature. A principle of order is the word: but what is meant, by a principle of order, as different from an intelligent Creator, has not been explained either by definition or example; and, without such explanation, it should seem to be a mere substitution of words for reasons, names for causes. Order itself is only the adaptation of means to an end: a principle of order, therefore, can only signify the mind and intention which so adapts them. Or, were it capable of being explained in any other sense, is there any experience, any analogy, *to sustain it?* Was a watch ever produced by a principle

of order? and why might not a watch be so produced, as well as an eye?

Furthermore, a principle of order, acting blindly and without choice, is negatived by the observation that order is not universal, which it would be, if it issued from a constant and necessary principle; nor indiscriminate, which it would be if it issued from an unintelligent principle. Where order is wanted, there we find it: where order is not wanted, *i. e.*, where, if it prevailed, it would be useless, there we do not find it. In the structure of the eye, (for we adhere to our example,) in the figure and position of its several parts, the most exact order is maintained. In the forms of rocks and mountains, in the lines which bound the coasts of continents and islands, in the shape of bays and promontories, no order whatever is perceived, because it would have been superfluous. No useful purpose would have arisen from moulding rocks and mountains into regular solids, bounding the channel of the ocean by geometrical curves; or from the map of the world resembling a table of diagrams in Euclid's Elements or Simpson's Conic Sections.

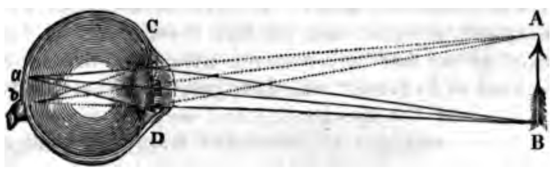
VII. Lastly; the confidence which we place in our observations upon the works of Nature, in the marks which we discover of contrivance, choice, and design, and in our reasoning upon the proofs afforded us, ought not to be shaken, as it is sometimes attempted to be done, by bringing forward to our view our own ignorance, or rather the general imperfection of our knowledge of Nature. Nor, in many cases, ought this consideration to affect us, even when it respects some parts of the subject immediately under our notice. True fortitude of understanding consists in not suffering what we know, to be disturbed by what we do not know. If we perceive a useful end, and means adapted to that end, we perceive enough for our conclusion. If these things be clear, no matter what is obscure. The argument is finished. For instance; if the utility of vision to the animal which enjoys it, and the adaptation of the *eye* to this office, be evident and certain, (and I can mention nothing which is more so,) ought it to *prejudice the inference* which we draw from these prem-

ises that we cannot explain the use of the spleen? Nay, more: if there be parts of the eye, viz., the cornea, the crystalline, the retina, in their substance, figure, and position, manifestly suited to the formation of an image by the refraction of rays of light, at least as manifestly as the glasses and tubes of a dioptric telescope are suited to that purpose, it concerns, not the proof which these afford of design, and of a designer, that there may, perhaps, be other parts, certain muscles, for instance, or nerves, in the same eye, of the agency or effect of which we can give no account, any more than we should be inclined to doubt, or ought to doubt about the construction of a telescope, viz., for what purpose it was constructed, or whether it were constructed at all, because there belonged to it certain screws and pins, the use or action of which we did not comprehend. I take it to be a general way of infusing doubts and scruples into the mind, to recur to its own ignorance, its own imbecility: to tell us that upon these subjects we know little, and that little imperfectly; or rather, that we know nothing properly about the matter. These suggestions so fall in with our consciousness, as sometimes to produce a general distrust of our faculties and our conclusions. But this is an unfounded jealousy. The uncertainty of one thing, does not necessarily affect the certainty of another thing. Our ignorance of many points, need not suspend our assurance of a few. Before we yield, in any particular instance, to the skepticism which this sort of insinuation would induce, we ought accurately to ascertain whether our ignorance or doubt concern those precise points upon which our conclusion rests. Other points are nothing. Our ignorance of other points may be of no consequence to these, though they be points, in various respects, of great importance. A just reasoner removes from his consideration, not only what he knows, but what he does not know, touching matters not strictly connected with his argument, *i. e.*, not forming the very steps of his deduction: beyond these, his knowledge and his ignorance are alike relative.

CHAPTER VI.

THE ARGUMENT CUMULATIVE.

WERE there no example in the world of contrivance except that of the eye, it would be alone sufficient to support the conclusion which we draw from it, as to the necessity of an intelligent Creator. It could never be got rid of; because it could not be accounted for by any other supposition, which did not contradict all the principles we possess of knowledge; the principles according to which things do, as often as they can be brought to the test of experience, turn out to be true or false. Its coats and humors, constructed, as the lenses of a tele-



[This figure is introduced to remind the reader of the fine adjustment of the eye ; A, B, is the object, and the lines represent the light reflected from it into the eye. On the surface of the cornea, which is the transparent part of the eye, the rays are in a certain degree refracted. Passing through the coat called cornea, they enter the aqueous humor. In their transmission through it, they pass into the pupil. They enter the lens or crystalline humor, and by the greater power of refraction in this humor, the rays are drawn to a point and impinge on the bottom of the eye at A, B. It will be further seen that the rays coming from B are refracted to *a*, those from A to *b*, and that the image is therefore represented inverted.]

scope are constructed, for the refraction of rays of light to a point, which forms the proper action of the organ; the provision in its muscular tendons for turning its pupil to the object, similar to that which is given to the telescope by screws, and upon which power of direction in

the eye the exercise of its office as an optical instrument depends; the further provision for its defence, for its constant lubricity and moisture, which we see in its socket and its lids, in its glands for the secretion of the matter of tears, its outlet or communication with the nose for carrying off the liquid after the eye is washed with it; these provisions compose altogether an apparatus, a system of parts, a preparation of means, so manifest in their design, so exquisite in their contrivance, so successful in their issue, so precious, and so infinitely beneficial in their use, as, in my opinion, to bear down all doubt that can be raised upon the subject. And what I wish, under the title of the present chapter, to observe, is, that if other parts of Nature were inaccessible to our inquiries, or even if other parts of Nature presented nothing to our examination but disorder and confusion, the validity of this example would remain the same. If there were but one watch in the world, it would not be less certain that it had a maker. If we had never in our lives seen any but one single kind of hydraulic machine, yet, if of that one kind we understood the mechanism and use, we should be as perfectly assured that it proceeded from the hand and thought and skill of a workman, as if we visited a museum of the arts, and saw collected there twenty different kinds of machines for drawing water, or a thousand different kinds for other purposes. Of this point each machine is a proof independently of all the rest. So it is with the evidences of a Divine agency. The proof is not a conclusion which lies at the end of a chain of reasoning, of which chain each instance of contrivance is only a link, and of which, if one link fail, the whole falls; but it is an argument separately supplied by every separate example. An error in stating an example affects only that example. The argument is cumulative, in the fullest sense of that term. The eye proves it without the ear; the ear without the eye. The proof in each example is complete; for, when the design of the part, and the conduciveness of its structure to that design is shown, the mind may set itself at rest; no future consideration can detract any thing from the *force of the* example.

CHAPTER VII.

OF THE MECHANICAL AND IMMECHANICAL PARTS AND FUNCTIONS OF ANIMALS AND VEGETABLES.

It is not that *every* part of an animal or vegetable has not proceeded from a contriving mind; or that every part is not constructed with a view to its proper end and purpose, according to the laws belonging to, and governing the substance or the action made use of in that part: or that each part is not so constructed as to effectuate its purpose whilst it operates according to these laws: but it is because these laws themselves are not in all cases equally understood; or, what amounts to nearly the same thing, are not equally exemplified in more simple processes, and more simple machines, that we lay down the distinction, here proposed, between the mechanical parts of animals and vegetables.[14]

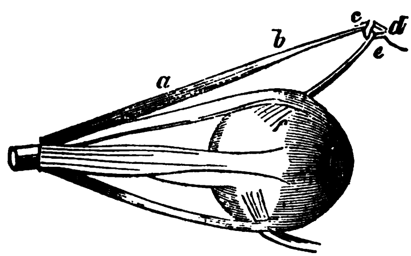
[The reader will not be easily convinced that the mass of flesh, with which he is familiar, is easily and almost spontaneously divided into distinct muscles. This figure represents a muscle. C is the belly of the muscle; A and B the tendons: A being the tendinous *origin*, as it is termed, attached to a fixed point of bone; B the tendinous *insertion*, being attached to a part movable by the contraction of the muscle. The belly, C, consists of fibres which are possessed of the power of contraction or irritability, and through the operation of which the various motions of the body are performed. We shall presently have to remark on the direction of these fibres.]

[14] The observation here is most sensible. When we speak of an organ as peculiarly suited to exhibit design, we mean merely that we comprehend something of the object of the particular structure. But there is no part of an animal, if we fully comprehended what was necessary to the performance of its functions, that would not raise our

For instance; the principle of muscular motion, viz., upon what cause the swelling of the belly of the muscle, and consequent contraction of its tendons, either by an act of the will, or by involuntary irritation, depends, is wholly unknown to us. The substance employed, whether it be fluid, gaseous, elastic, electrical, or none of these, or nothing resembling these, is also unknown to us; of course, the laws belonging to that substance, and which regulate its action, are unknown to us. We see nothing similar to this contraction in any machine which we can make, or any process which we can execute. So far (it is confessed) we are in ignorance, but no further. This power and principle, from whatever cause it proceeds, being assumed, the collocation of the fibres to receive the principle, the disposition of the muscles for the use and application of the power, is mechanical; and is as intelligible as the adjustment of the wires and strings by which a puppet is moved. We see, therefore, as far as respects the subject before us, what is not mechanical in the animal frame, and what is. The nervous influence (for we are often obliged to give names to things which we know little about)—I say the nervous influence, by which the belly or middle of the muscle is swelled, is not mechanical. The utility of the effect, we perceive; the means, or the preparation of means, by which it is produced, we do not. But obscurity as to the origin of muscular motion, brings no doubtfulness into our observations upon the sequel of the process: which observations relate—1st, to the constitution of the muscle, in conse-

admiration. Were we to take a portion of the skin, and contemplate its exquisite sensibility, so finely appropriated; could we penetrate, as it were, into the pores, and duly estimate the power which regulates the secretions and absorption; could we fully understand the relations of this organ, either with the economy of the body within, or the constitution of the atmosphere without;—we should have no occasion to draw our argument, for the twentieth time, from the structure of the eye or the ear. Were we to take one cell of the millions of that substance which, intervening between the more solid textures of the frame, gives elasticity to the whole, and permits circulation and muscular action, and all the various movements of the body, we should have, in that one cell, as much reason for wonder at the perfection of the contrivance, as in any joint of the limb.—Eng. Ed.

quence of which constitution, the swelling of the belly or middle part is necessarily and mechanically followed by a contraction of the tendons; 2dly, to the number and variety of the muscles, and the corresponding number and variety of useful powers which they supply to the animal, which is astonishingly great; 3dly, to the judicious, (if we may be permitted to use that term in speaking of the Author, or of the works, of Nature,) to the wise and well-contrived disposition of each muscle for its specific purpose; for moving the joint this way, and that way, and the other way; for pulling and drawing the part to which it is attached in a determinate and particular direction: which is a mechanical operation exemplified in a multitude of instances. To mention only one: The tendon of the trochlear muscle of the eye, to the end that it may draw in the line required, is passed through a cartilaginous ring, at which it is reverted, exactly in the same manner as a rope in a ship is carried over a block, or round a stay, in order to make it pull in the direction which is wanted.



[*a*, the fleshy part of the trochlear muscle; *b*, *c*, *e*, the tendon of the muscle, passing through a pulley, *d*, and inserted in the eyeball at *f*.—AM. ED.]

All this, as we have said, is mechanical, and is as accessible to inspection, as capable of being ascertained, as the mechanism of the automaton in the Strand. Supposing the automaton to be put in motion by a magnet, (which is probable,) it will supply us with a comparison very apt for our present purpose. Of the magnetic effluvium we *know perhaps* as little as we do of the nervous fluid.

But, magnetic attraction being assumed, (it signifies nothing from what cause it proceeds,) we can trace, or there can be pointed out to us, with perfect clearness and certainty, the mechanism, viz., the steel bars, the wheels, the joints, the wires, by which the motion, so much admired, is communicated to the fingers of the image; and to make any obscurity, or difficulty, or controversy in the doctrine of magnetism, an objection to our knowledge or our certainty concerning the contrivance, or the marks of contrivance, displayed in the automaton, would be exactly the same thing as it is to make our ignorance (which we acknowledge) of the cause of nervous agency, or even of the substance and structure of the nerves themselves, a ground of question or suspicion as to the reasoning which we institute concerning the mechanical part of our frame. That an animal is a machine, is a proposition neither correctly true nor wholly false. The distinction which we have been discussing, will serve to show how far the comparison, which this expression implies, holds; and wherein it fails. And whether the distinction be thought of importance or not, it is certainly of importance to remember, that there is neither truth nor justice in endeavoring to bring a cloud over our understandings, or a distrust into our reasonings upon this subject, by suggesting that we know nothing of voluntary motion, of irritability, of the principle of life, of sensation, of animal heat, upon all which the animal functions depend; for, our ignorance of these parts of the animal frame concerns not at all our knowledge of the mechanical parts of the same frame. I contend, therefore, that there is mechanism in animals; that this mechanism is as properly such, as it is in machines made by art; that this mechanism is intelligible and certain; that it is not the less so, because it often begins or terminates with something which is not mechanical; that whenever it is intelligible and certain, it demonstrates intention and contrivance, as well in the works of Nature, as in those of art; and that it is the best demonstration which either can afford.

But, whilst I contend for these propositions, I do not *exclude* myself from asserting, that there may be, and

that there are, other cases, in which, although we cannot exhibit mechanism, or prove indeed that mechanism is employed, we want not sufficient evidence to conduct us to the same conclusion.

There is what may be called the *chemical* part of our frame; of which, by reason of the imperfection of our chemistry, we can attain to no distinct knowledge; I mean, not to a knowledge, either in degree or kind, similar to that which we possess of the mechanical part of our frame. It does not, therefore, afford the same species of argument as that which mechanism affords; and yet it may afford an argument in a high degree satisfactory. The *gastric juice*, or the liquor which digests the food in the stomachs of animals, is of this class. Of all the menstrua it is the most active, the most universal. In the human stomach, for instance, consider what a variety of strange substances, and how widely different from one another, it in a few hours reduces to a uniform pulp, milk, or mucilage. It seizes upon every thing; it dissolves the texture of almost every thing that comes in its way. The flesh of perhaps all animals; the seeds and fruits of the greatest number of plants; the roots, and stalks, and leaves of many, hard and tough as they are, yield to its powerful pervasion. The change wrought by it, is different from any chemical solution which we can produce, or with which we are acquainted, in this respect, as well as many others, that, in our chemistry, particular menstrua act only upon particular substances. Consider, moreover, that this fluid, stronger in its operation than a caustic alkali or mineral acid, than red precipitate, or aquafortis itself, is nevertheless as mild, and bland, and inoffensive to the touch or taste as saliva or gum-water, which it much resembles. Consider, I say, these several properties of the digestive organ, and of the juice with which it is supplied, or rather with which it is made to supply itself, and you will confess it to be entitled to a name which it has sometimes received, that of "the chemical wonder of animal nature."

Still we are ignorant of the composition of this fluid, and of the mode of its action; by which is meant, that *we are not capable*, as we are in the mechanical part of

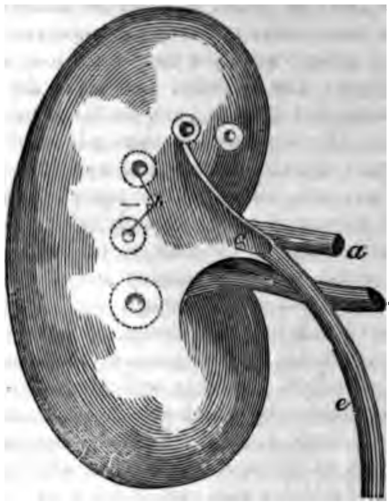
our frame, of collating it with the operations of art. And this I call the imperfection of our chemistry; for, should the time ever arrive, which is not, perhaps, to be despaired of, when we can compound ingredients so as to form a solvent which will act in the manner in which the gastric juice acts, we may be able to ascertain the chemical principles upon which its efficacy depends, as well as from what part, and by what concoction, in the human body, these principles are generated and derived.

In the mean time, ought that, which is in truth the defect of our chemistry, to hinder us from acquiescing in the inference which a production of Nature, by its place, its properties, its action, its surprising efficacy, its invaluable use, authorizes us to draw in respect of a creative design?[15]

Another most subtile and curious function of animal bodies is *secretion*. This function is semi-chemical and semi-mechanical; exceedingly important and diversified in its effects, but obscure in its process and in its apparatus. The importance of the secretory organs is but too well attested by the diseases which an excessive, a deficient, or a vitiated secretion is almost sure of producing. A single secretion being wrong is enough to make life miserable, or sometimes to destroy it. Nor is the variety less than the importance. From one and the same blood (I speak of the human body) about twenty different fluids are separated; in their sensible properties, in taste, smell, color, and consistency, the most unlike one another that is possible; thick, thin, salt, bitter, sweet: and if from

[15] After this enumeration of the things dissolved by the gastric juice, the most extraordinary fact remains to be stated, that the delicate surface of the stomach itself, softer and finer than the surface of the eye, remains untouched by this humor, which our author, somewhat quaintly, describes as more powerful to dissolve than aquafortis. John Hunter showed us that it was the property of life that protected the coats of the stomach. This fact is a most singular proof of the power bestowed through life on the membranes and vessels; and it is as important as it is curious: for as the stomach in the dead body no longer resists this menstruum, it may become dissolved, if the person has died with the fluid already secreted into the stomach. And so it has happened that persons have been supposed to be poisoned, and relations have been falsely accused, from the stomach being found eroded as if some acrid poison had been taken before death.—Eng. Ed.

our own, we pass to other species of animals, we find amongst their secretions not only the most various but the most opposite properties; the most nutritious aliment, the deadliest poison; the sweetest perfumes, the most fetid odors. Of these the greater part, as the gastric juice, the saliva, the bile, the slippery mucilage which lubricates the joints, the tears which moisten the eye, the wax which defends the ear, are, after they are secreted, made use of in the animal economy; are evidently subservient, and are actually contributing, to the utilities of the animal itself. Other fluids seem to be separated only to be rejected. That this also is necessary, (though why it was originally necessary we cannot tell,) is shown, by the consequence of the separation being long suspended, which consequence is, disease and death. Akin to secretion, if not the same thing, is assimilation, by which one and the same blood is converted into bone, muscular flesh, nerves, membranes, tendons; things as different as the wood and iron, canvass and cordage, of which a ship with its furniture is composed. We have no operation of art wherewith exactly to compare all this, for no other reason, perhaps, than that all operations of art are exceeded by it. No chemical election, no chemical analysis or resolution of a substance into its constituent parts, no mechanical sifting or division that we are acquainted with, in perfection or variety come up to animal secretion. Nevertheless, the apparatus and process are obscure, not to say absolutely concealed from our inquiries. In a few and only a few instances, we can discern a little of the constitution of a gland. In the kidneys of large animals, we can trace the emulgent artery dividing itself into an infinite number of branches; their extremities every where communicating with little round bodies, in the substance of which bodies the secret of the machinery seems to reside, for there the change is made. We can discern pipes laid from these round bodies towards the pelvis, which is a basin within the solid of the kidney. We can discern these pipes joining and collecting together into larger pipes; and, when so collected, ending in innumerable papillæ, through which the secreted fluid is *continually oozing into* its receptacle. This is all we know



[*a*, the artery by which blood is carried to the kidney; *d*, the vein by which the blood is returned; *b*, the minute tubes by which the secreted fluid is brought from various parts of the kidney to *c*, the entrance into the tube *e*, through which the fluid is transmitted to its receptacle or reservoir. —Am. Ed.]

of the mechanism of a gland, even in the case in which it seems most capable of being investigated. Yet to pronounce that we know nothing of animal secretion, or nothing satisfactorily, and with that concise remark to dismiss the article from our argument, would be to dispose of the subject very hastily and very irrationally. For the purpose which we want, that of evincing intention, we know a great deal. And what we know is this. We see the blood carried by a pipe, conduit, or duct, *to* the gland. We see an organized apparatus, be its construction or action what it will, which we call that gland. We see the blood, or part of the blood, after it has passed through and undergone the action of the gland, coming *from* it by an emulgent vein or artery, i. e., by another pipe or conduit. And we see also, at the same time, a new and specific

fluid issuing from the same gland by its excretory duct, *i.e.*, by a third pipe or conduit; which new fluid is in some cases discharged out of the body, in more cases retained within it, and there executing some important and intelligent office. Now, supposing, or admitting, that we know nothing of the proper internal constitution of a gland, or of the mode of its acting upon the blood, then our situation is precisely like that of an unmechanical looker-on, who stands by a stocking-loom, a corn-mill, a carding-machine, or a threshing-machine, at work, the fabric and mechanism of which, as well as all that passes within, is hidden from his sight by the outside case; or, if seen, would be too complicated for his uninformed, uninstructed understanding to comprehend. And what is that situation? This spectator, ignorant as he is, sees at one end a material enter the machine, as unground grain the mill, raw cotton the carding-machine, sheaves of unthreshed corn the threshing-machine; and, when he casts his eye to the other end of the apparatus, he sees the material issuing from it in a new state; and, what is more, in a state manifestly adapted to future uses; the grain in meal fit for the making of bread, the wool in rovings ready for spinning into threads, the sheaf in corn dressed for the mill. Is it necessary that this man, in order to be convinced that design, that intention, that contrivance has been employed about the machine, should be allowed to pull it to pieces; should be enabled to examine the parts separately; explore their action upon one another, or their operation, whether simultaneous or successive, upon the material which is presented to them? He may long to do this to gratify his curiosity; he may desire to do it to improve his theoretic knowledge; or he may have a more substantial reason for requesting it, if he happen, instead of a common visiter, to be a millwright by profession, or a person sometimes called in to repair such-like machines when out of order; but for the purpose of ascertaining the existence of counsel and design in the formation of the machine, he wants no such intromission or privity. What he sees, is sufficient. The effect upon the material, the *change produced* in it, the utility of that change for future

applications, abundantly testify, be the concealed part of the machine or of its construction what it will, the hand and agency of a contriver.

If any confirmation were wanting to the evidence which the animal secretions afford of design, it may be derived, as has been already hinted, from their variety, and from their appropriation to their place and use. They all come from the same blood; they are all drawn off by glands; yet the produce is very different, and the difference exactly adapted to the work which is to be done, or the end to be answered. No account can be given of this, without resorting to appointment. Why, for instance, is the saliva, which is diffused over the seat of taste, insipid, whilst so many others of the secretions, the urine, the tears, and the sweat, are salt? Why does the gland within the ear separate a viscid substance, which defends that passage; the gland in the upper angle of the eye a thin brine, which washes the ball? Why is the synovia of the joints mucilaginous; the bile bitter, stimulating, and soapy? Why does the juice which flows into the stomach contain powers which make that bowel the great laboratory, as it is by its situation the recipient, of the materials of future nutrition? These are all fair questions; and no answer can be given to them but what calls in intelligence and intention.

My object in the present chapter has been to teach three things: first, that it is a mistake to suppose that, in reasoning from the appearances of Nature, the imperfection of our knowledge proportionably affects the certainty of our conclusion; for in many cases it does not affect it at all: secondly, that the different parts of the animal frame may be classed and distributed according to the degree of exactness with which we compare them with works of art: thirdly, that the *mechanical* parts of our frame, or those in which this comparison is most complete, although constituting, probably, the coarsest portions of Nature's workmanship, are the most proper to be alleged as proofs and specimens of design.

CHAPTER VIII.

OF MECHANICAL ARRANGEMENT IN THE HUMAN FRAME.

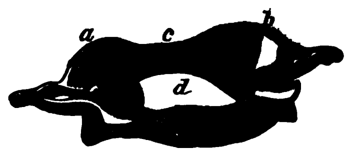
[This figure represents the lower surface or base of the skull. The hole is the *foramen magnum* through which the spinal marrow descends into the spine; and on each side of the hole are the articulating processes, called the *condyles.*]

We proceed, therefore, to propose certain examples, taken out of this class; making choice of such as, amongst those which have come to our knowledge, appear to be the most striking and the best understood; but obliged, perhaps, to postpone both these recommendations to a third: that of the example being capable of explanation without plates, or figures, or technical language.

OF THE BONES.

I. I challenge any man to produce, in the joints and *pivots of the most* complicated or the most flexible ma-

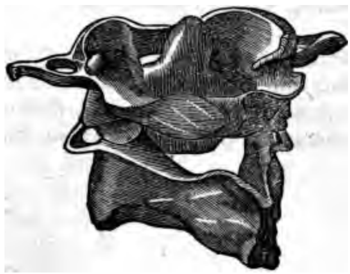
chine that was ever contrived, a construction more artificial, or more evidently artificial, than that which is seen in the vertebræ of the *human neck*. Two things were to be done: the head was to have the power of bending forward and backward, as in the act of nodding, stooping, looking upward or downward; and, at the same time, of turning itself round upon the body to a certain extent,—the quadrant, we will say, or rather, perhaps, a hundred and twenty degrees of a circle. For these two purposes, two distinct contrivances are employed: first, the head rests immediately upon the uppermost part of the vertebræ, and is united to it by a *hinge*-joint; upon which joint the head plays freely forward and backward, as far either way as is necessary, or as the ligaments allow; which was the first thing required. But then the rotatory motion is unprovided for: therefore, secondly, to make the head capable of this, a further mechanism is introduced: not between



[This figure represents the uppermost vertebra, or atlas; and the condyles, mentioned in the former figure, sink into the articulating surfaces of this vertebra, permitting the nodding motions; *a* and *b* are the articulating surfaces; *c* is a surface which receives the tooth of the vertebra below; *d*, the circle through which the spinal marrow passes.]

the head and the uppermost bone of the neck, where the hinge is, but between that bone and the bone next underneath it. It is a mechanism resembling a *tenon and mortise*. This second, or uppermost bone but one, has what anatomists call a process, viz., a projection, somewhat similar, in size and shape, to a tooth; which tooth, entering a corresponding hole or socket in the bone above it, forms a pivot or axle, upon which that upper bone, together with the head which it supports, turns freely in a circle; and as far in the circle as the attached muscles permit the head to turn. Thus are both motions perfect without

interfering with each other. When we nod the head, we use the hinge-joint, which lies between the head and the first bone of the neck. When we turn the head round, we use the tenon and mortise, which runs between the first bone of the neck and the second.[16]



[Here the tooth-like process of the second vertebra, which is called *dentata*, is passed through the ring of the first, and is held there by a transverse ligament, like a spindle in the bush. No doubt the object of this complexity is to permit the free motion of the head, without too great a laxity at any one joining, and thereby to protect the most vital organ of the body, the *medulla oblongata* or spinal marrow, which passes from the head into the tube of the spine.]

We see the same contrivance, and the same principle, employed in the frame or mounting of a telescope. It is occasionally requisite that the object-end of the instrument be moved up and down, as well as horizontally, or equatorially. For the vertical motion, there is a hinge, upon which the telescope plays; for the horizontal or equatorial motion, an axis upon which the telescope and the hinge turn round together. And this is exactly the mechanism which is applied to the motion of the head; nor will any one here doubt of the existence of counsel and design, except it be by that debility of mind, which can trust to its own reasonings in nothing.

[16] The meaning of our author is obvious here; but the tenon and mortise are terms used for the firm joining of beams, as in the carpentry of a roof; not for rotatory motion.—Eng. Ed.

We may add, that it was, on another account, also expedient that the motion of the head backward and forward should be performed upon the upper surface of the first vertebra; for, if the first vertebra itself had bent forward, it would have brought the spinal marrow, at the very beginning of its course, upon the point of the tooth.

II. Another mechanical contrivance, not unlike the last in its object, but different and original in its means, is seen in what anatomists call the *fore-arm*,—that is, in the arm between the elbow and the wrist. Here, for the perfect

[Since it has been our author's pleasure to take this instance, the figure will illustrate his description. A is the lower part of the arm-bone, or *humerus*; B is the *ulna* and C the *radius*, the two bones of the fore-arm. It will be understood how these bones, being tied together by ligaments, hinge and move upon the humerus, A; *c* being the process of the ulna, on which we rest when leaning on the elbow. By applying our hand to the arm, we at once feel the freedom with which the bone moves in bending and extending the arm. When we turn the key in a lock, or make the guards in fencing, by the motion of the wrist, the ulna, B, is stationary, and the radius, C, turns round upon the head of the bone at *d* and *e*, carrying the hand with it. The rest is abundantly well explained in the text.]

use of the limb, two motions are wanted ; a motion at the elbow, backward and forward, which is called a reciprocal motion ; and a rotatory motion, by which the palm of the hand, as occasion requires, may be turned upward. How is this managed ? The fore-arm, it is well known, consists of two bones, lying alongside each other, but touching only toward the ends. One, and only one, of these bones is joined to the cubit, or upper part of the arm, at the elbow ; the other alone to the hand at the wrist. The first, by means, at the elbow, of a hinge-joint, (which allows only of motion in the same plane,) swings backward and forward, carrying along with it the other bone, and the whole fore-arm. In the mean time, as often as there is occasion to turn the palm upward, that other bone to which the hand is attached rolls upon the first, by the help of a groove or hollow near each end of one bone, to which is fitted a corresponding prominence in the other. If both bones had been joined to the cubit, or upper arm, at the elbow, or both to the hand, at the wrist, the thing could not have been done. The first was to be at liberty at one end, and the second at the other ; by which means, the two actions may be performed together. The great bone which carries the fore-arm, may be swinging upon its hinge at the elbow, at the very time that the lesser bone, which carries the hand, may be turning round it in the grooves. The management, also, of these grooves, or rather of the tubercles and grooves, is very observable. The two bones are called, the *radius* and the *ulna*. Above, *i. e.*, towards the elbow, a tubercle of the radius plays into a socket of the ulna ; whilst below, *i. e.*, towards the wrist, the radius finds the socket, and the ulna the tubercle. A single bone in the fore-arm, with a ball-and-socket joint at the elbow, which admits of motion in all directions, might, in some degree, have answered the purpose of both moving the arm and turning the hand. But how much better it is accomplished by the present mechanism, any person may convince himself, who puts the ease and quickness with which he can shake his hand at the wrist, circularly, (moving likewise, if he pleases, his arm, at the elbow, at the same time,) in com-

petition with the comparatively slow and laborious motion with which his arm can be made to turn round at the shoulder by the aid of a ball-and-socket joint.

III. The *spine*, or back-bone, is a chain of joints of very wonderful construction. Various, difficult, and almost inconsistent offices were to be executed by the same instrument. It was to be firm, yet flexible, (now, I know no chain, made by art, which is both these; for by firmness I mean, not only strength, but stability;) *firm*, to support the erect position of the body; *flexible*, to allow of the bending of the trunk in all degrees of curvature. It was further, also, (which is another and quite a distinct purpose from the rest,) to become a pipe or conduit for the safe conveyance from the brain of the most important fluid of the animal frame, that, namely, upon which all voluntary motion depends, the spinal marrow; a substance not only of the first necessity to action, if not to life, but of a nature so delicate and tender, so susceptible and so impatient of injury, as that any unusual pressure upon it, or any considerable obstruction of its course, is followed by paralysis or death. Now the spine was not only to furnish the main trunk for the passage of the medullary substance from the brain, but to give out, in the course of

[This represents a section of the lower vertebræ.]

its progress, small pipes therefrom, which, being afterwards indefinitely subdivided, might, under the name of nerves, distribute this exquisite supply to every part of the body. The same spine was also to serve another use, not less wanted than the preceding, viz., to afford a fulcrum, stay, or basis, (or, more properly speaking, a series of these,) for the insertion of the muscles which are spread over the trunk of the body; in which trunk there are not, as in the limbs, cylindrical bones to which they can be fastened: and likewise, which is a similar use, to furnish a support for the ends of the ribs to rest upon.

Bespeak of a workman a piece of mechanism which shall comprise all these purposes, and let him set about to contrive it; let him try his skill upon it; let him feel the difficulty of accomplishing the task, before he be told how the same thing is effected in the animal frame. Nothing will enable him to judge so well of the wisdom which has been employed; nothing will dispose him to think of it so truly. First, for the firmness, yet flexibility, of the spine; it is composed of a great number of bones, (in the human subject, of twenty-four,) joined to one another, and compacted by broad bases. The breadth of the bases upon which the parts severally rest, and the closeness of the junction, give to the chain its firmness and stability; the number of parts, and consequent frequency of joints, its flexibility. Which flexibility, we may also observe, varies in different parts of the chain; is least in the back, where strength, more than flexure, is wanted; greater in the loins, which it was necessary should be more supple than the back; and greatest of all in the neck, for the free motion of the head. Then, secondly, in order to afford a passage for the descent of the medullary substance, each of these bones is bored through in the middle, in such a manner as that, when put together, the hole in one bone falls into a line and corresponds with the holes in the two bones contiguous to it. By which means the perforated pieces, when joined, form an entire, close, uninterrupted channel, at least while the spine is upright and at rest. But as a settled posture is inconsistent with its use, a great *difficulty still* remained, which was to prevent the verte-

bræ shifting upon one another, so as to break the line of the canal as often as the body moves or twists, or the joints gaping externally whenever the body is bent forward and the spine thereupon made to take the form of a bow. These dangers, which are mechanical, are mechanically provided against. The vertebræ, by means of their processes and projections, and of the articulations which some of these form with one another at their extremities, are so locked in and confined, as to maintain, in what are called the bodies or broad surfaces of the bones, the relative position nearly unaltered, and to throw the change and the pressure produced by flexion almost entirely upon the intervening cartilages, the springiness and yielding nature of whose substance, admits of all the motion which is necessary to be performed upon them, without any chasm being produced by a separation of the parts. I say, of all the motion which is necessary; for, although we bend our backs to every degree almost of inclination, the motion of each vertebra is very small: such is the advantage we receive from the chain being composed of so many links, the spine of so many bones. Had it consisted of three or four bones only, in bending the body, the spinal marrow must have been bruised at every angle. The reader need not be told that these intervening cartilages are gristles, and he may see them in perfection in a loin of veal. Their form also favors the same intention. They are thicker before than behind; so that, when we stoop forward, the compressible substance of the cartilage, yielding in its thicker and anterior part to the force which squeezes it, brings the surface of the adjoining vertebræ nearer to the being parallel with one another than they were before, instead of increasing the inclination of their planes, which must have occasioned a fissure or opening between them. Thirdly, for the medullary canal giving out in its course, and in a convenient order, a supply of nerves to different parts of the body, notches are made in the upper and lower edge of every vertebra, two on each edge, equidistant on each side from the middle line of the back. When the vertebræ are put together, these notches, exactly fitting, form small holes, through which the nerves,

at each articulation, issue out in pairs, in order to send their branches to every part of the body, and with an equal bounty to both sides of the body. The fourth purpose assigned to the same instrument is the insertion of the bases of the muscles, and the support of the ends of the ribs; and for this fourth purpose, especially the former part of it, a figure, specifically suited to the design, and unnecessary for the other purposes, is given to the constituent bones. Whilst they are plain, and round, and smooth towards the front, where any roughness or projection might have wounded the adjacent viscera, they run out, behind, and on each side, into long processes, to which processes the muscles necessary to the motions of the trunk are fixed, and fixed with such art, that, whilst the vertebræ supply a basis for the muscles, the muscles help to keep these bones in their position, or by their tendons to tie them together.

That most important, however, and general property, viz., the strength of the compages, and the security against luxation, was to be still more specially consulted; for, where so many joints were concerned, and where, in every one, derangement would have been fatal, it became a subject of studious precaution. For this purpose the vertebræ are articulated, that is, the movable joints between them are formed, by means of those projections of their substance, which we have mentioned under the name of processes, and these so lock in with and overwrap one another, as to secure the body of the vertebræ not only from accidentally slipping, but even from being pushed out of its place by any violence, short of that which would break the bone. I have often remarked and admired this structure in the chine of a hare. In this, as in many instances, a plain observer of the animal economy may spare himself the disgust of being present at human dissections, and yet learn enough for his information and satisfaction, by even examining the bones of the animals which come upon his table. Let him take, for example, into his hands a piece of the clean-picked bone of a hare's back, consisting, we will suppose, of three vertebræ. He will find the middle bone of the three so implicated, by

means of its projections or processes, with the bone on each side of it, that no pressure which he can use will force it out of its place between them. It will give way neither forward nor backward, nor on either side. In whichever direction he pushes, he perceives, in the form, or junction, or overlapping of the bones, an impediment opposed to his attempt, a check and guard against dislocation. In one part of the spine he will find a still further fortifying expedient, in the mode according to which the vertebræ are annexed to the spine. Each rib rests upon two vertebræ. That is the thing to be remarked, and any one may remark it in carving a neck of mutton. The manner of it is this : the end of the rib is divided by a middle ridge into two surfaces, which surfaces are joined to the bodies of two contiguous vertebræ, the ridge applying itself to the intervening cartilage. Now this is the very contrivance which is employed in the famous iron bridge at my door at Bishop-Wearmouth, and for the same purpose of stability, viz., the cheeks of the bars which pass between the arches, ride across the joints by which the pieces composing each arch are united. Each cross-bar rests upon two of these pieces at their place of junction, and by that position resists, at least in one direction, any tendency in either piece to slip out of its place. Thus perfectly, by one means or the other, is the danger of slipping laterally, or of being drawn aside out of the *line* of the back, provided against; and to withstand the bones being pulled asunder longitudinally, or in the direction of that line, a strong membrane runs from one end of the chain to the other, sufficient to resist any force which is ever likely to act in the direction of the back or parallel to it, and consequently to secure the whole combination in their places. The general result is, that not only the motions of the human body, necessary for the ordinary offices of life, are performed with safety, but that it is an accident, hardly ever heard of, that even the gesticulations of a harlequin distort his spine.

Upon the whole, and as a guide to those who may be inclined to carry their considerations of this subject further, there are three views under which the spine ought to

be regarded, and in all which it cannot fail to excite our admiration. These views relate to its articulations, its ligaments, and its perforation; and to the corresponding advantages which the body derives from it, for action, for strength, and for that which is essential to every part, a secure communication with the brain.

The structure of the spine is not in general different in different animals.[17] In the serpent tribe, however, it is considerably varied; but with a strict reference to the convenience of the animal. For whereas in quadrupeds the number of vertebræ is from thirty to forty, in the serpent it is nearly one hundred and fifty: whereas in men and quadrupeds the surfaces of the bones are flat, and these flat surfaces laid one against the other, and bound

[17] There is a notion entertained by the ingenious and somewhat fanciful physiologists of France, that the extremities of the body, the parts furthest removed from the centre, are most subject to change in their conformation, whilst the central parts of the system are the most unvarying. Entertaining such a view, we lose much of the interest that is attached to the subject; and the inference which it is important to draw is forgotten, the accommodation not of parts only, but of the whole framework of the animal body, to the peculiar condition or necessities of the creature. The teeth vary because the food is different; the feet vary, because the mode of progression is different; the claws vary in connexion with the teeth, and the mode of procuring food, by digging, or scraping, or by holding and tearing. So does the eye, and so does the ear. But with these adaptations of parts, we must not lose sight of the fact which is the most important to our conclusions, that the whole is accommodated, as well as the individual organs.

The spine, in all vertebrated animals, holds its office in perpetuity; it contains and protects the spinal marrow; and, so far as its office is permanent, there will be a uniformity in its appearance in all creatures. But even in man, it varies in its structure, in the different portions or divisions of it, as these portions are required to admit of more or less freedom of motion. In the hare, as mentioned in the text, the spine is beautifully accommodated to the motion in running. In the cat-kind, as the leopard or tiger, it has a lateral mobility, quite different from its structure in the horse or stag. In the boar, the vertebræ are unusually firm, and the processes enormously extended, to give strength to the union with the head, and to direct the action of the muscles upon the head, so that he may tear up strong roots and possess his defence in his powerful tusks. In short, as far as the spine is required to accommodate itself to the motions of the trunk, it is varied with as fine an adjustment as the furthest bone of the toe or finger.—ENG. ED.

tight by sinews; in the serpent, the bones play one within another, like a ball and socket,* so that they have a free motion upon one another in every direction: that is to say, in men and quadrupeds, firmness is more consulted; in serpents, pliancy. Yet even pliancy is not obtained at the expense of safety. The back-bone of a serpent, for coherence and flexibility, is one of the most curious pieces of animal mechanism with which we are acquainted. The chain of a watch, (I mean the chain which passes between the spring-barrel and the fusee,) which aims at the same properties, is but a bungling piece of workmanship in comparison with that of which we speak.

[OF THE SPINE.

The spine is the most perfect structure in the whole animal machine. Perhaps, if our words were critically taken, it would be better to say, that the intention of the curious mechanical structure here was the most apparent, and, on that account, most the object of our admiration. By the skeleton, is meant the collection of bones which gives form and strength to the superior class of animals; and, as these bones are bound together by a chain of vertebræ, the whole class of these animals is called *vertebrata*, from this most essential part of the skeleton. Besides thus binding the bones together, and forming, as it were, the very centre of the whole, the spine is a tube for protecting the most vital organ of all—the spinal marrow. But, again, when we look upon the skeleton of man as giving him the power of standing erect, we observe that the spine, whilst it retains its other offices, has a new one imposed upon it: it is a pillar for sustaining, not only the superior parts of the body, but the globe of the head, which we shall find it protects, in a very unexpected manner. The reason of our admiration, then, is in being able to perceive the modes by which these different offices are performed by the construction of this column: how Nature has established the most opposite and inconsistent functions in one set of bones;--for these bones are so strong

* Der. Phys. Theol. p. 396.

as not to suffer under the longest fatigue or the greatest weight, which the limbs can bear; and so flexible, as to perform the chief turnings and bendings of the body; and yet so steady, withal, as to contain and defend the most material and the most delicate part of the nervous system.

In some animals, the lowest of the vertebrata, the protecting texture of the spinal marrow hardly deserves the name of vertebral column. In certain fishes,* for example, the spine consists of a cartilage, made tough by ligamentous intertexture. In the myxine, this cartilage does not entirely enclose the spinal marrow; for it lies in a deep groove on the upper part of the spine. But let us not suppose, that in fishes there is any imperfection in the vertebral column; it is an elastic column, on which the muscles act so as to become the means of powerful locomotion; and in all fishes, the spine has, more or less, this remarkable elasticity. Ascending in the scale of animals, we find the cartilage forming the spinal column subdivided by cavities, which contain a gelatinous fluid; and these cavities being surrounded with a strong but elastic ligamentous covering, nothing can be conceived more admirably adapted to give a springiness to the whole column. Still ascending, we discover that the bony matter becomes deposited between these cavities; and here the separate vertebræ first appear. If two vertebræ of the great shark be taken out together, and the sac between them punctured, such is the elasticity of the walls of this sac, that the fluid will be spouted out to a distance. In other fishes, as the codfish, (an osseous fish,) the structure approaches to that of the mammalia; the intervertebral substance is gelatinous. In the whales, circular concentric ligaments join the vertebræ, and a small portion in the centre consists of a glairy matter. In mammalia, and in man, there are strong and distinct bones of the vertebræ; and these are joined by a ligamentous cartilage, the outer circle of which, is remarkably strong, and the central, soft and elastic. The toughness and strength of the exterior circle, and the soft condition of the centre,

* Myxine, lamprey, sturgeon, &c.

make a joint equivalent in action, to what might be produced by a ball intervening between the surfaces : a facility of motion is thus bestowed, which no form of solid could give ; and yet the joint is so strong, that the bone breaks from violence, but the ligamentous cartilage never gives way. When the veterinary surgeon casts a horse, if he be not careful to restrain him, he will twist himself with a force which will break the vertebræ. It is a frequent accident in man ; but the texture, that gives mobility to the spine, never yields.

The next thing admirable in the spine, is the manner in which the head is sustained, on a column possessing elasticity, and in which the brain is thereby saved from undue concussion, in the movements of the body. This object is not attained altogether through the elastic substance in the spine, which we have described ; but it is owing, in a great measure, to the general form of the spine in man. Had the vertebræ been built up, like a lofty column, of portions put correctly and vertically over one another, the spine would not have had the advantages which result from the structure that we have to describe. As the incumbent weight would then have fallen on the centres of all the bodies of the vertebræ, they must have yielded in a slight degree only. Accordingly, the figure of the italic *f* is given to the column, which waving line we need not admire because it is the line of beauty, as some have defined it, but because it is the form of elasticity. The spine being already in a curved shape, it bends easily; the pressure is directed upon the margins of the vertebræ, and of the intervertebral substances, and they therefore yield readily ; and by yielding, they produce an increase of the curve, a consequent shortening of the whole column, and admit an easy return to their original places. Suppose we rest the palm of the hand upon a walking-cane, which is elastic, but perfectly straight ; it bears a considerable pressure without yielding, and when it does yield, it is with a jerk ; but if it be previously bent, however we may increase or diminish the pressure, there will be no shock : the hand will be supported, or the cane *yield*, with an easy and uninterrupted resiliency. Such

we conceive to be the end obtained through the double curvature of the spine: that the brain shall receive no shock, in the sudden motions of the body.

Were we to give our attention to the processes of bone which stand out from the bodies of the vertebræ, we should find unexpected provisions there also. It is a common remark of anatomists, that the bones of the spine are secured in their proper places, by the relations of the surfaces in contact; the surface of the body being oblique in one direction, and those of the articulating processes in another; the one, therefore, preventing the bone being dislocated forwards, and the others preventing it being displaced backwards. There is something more than this. The articulating processes consist of two broad surfaces, which are inclined in such a manner that they slide upon one another; that is to say, the articulating surface of the vertebra above, being itself inclined, rests upon another which is also inclined. As the intervertebral substances of the bodies yield and recoil, the articulating process of the upper vertebra shifts upon the inclined surface of the process on which it is seated, ascending and descending; but the impediment is greater, the more the vertebra descends, thus adding to the elasticity and security of the whole, and preventing the abrupt shocks, which would be the consequence of the surfaces being horizontal. If a cannon were made to recoil upon an ascending plane, or a surface forming a portion of a circle, it would present the mechanism of the articulating processes of the vertebræ.

Let the separate spine be presented before us, it stands up, like a mast, broad and strong below, and tapering upwards. The mast of a ship is supported by the shrouds and stays; and if we sought for an analogy with these, we must fix upon the long muscles of the back, which run along the spine to sustain it. But as a mast goes by the board in a storm, we see where the spine would have been most in danger, had not Nature provided against it. When we start forward in walking or running, it is by the exertion of the muscles of the lower extremities, and the body follows. Did the spine stand directly up, perpendicularly, it would sustain a shock or jar at its base, in

these sudden motions. We see, therefore, the intention of the lower vertebræ being inclined forwards from their foundation on the sacrum: for, by this means, the jar which might endanger the junction of the lowest piece, is divided amongst the five pieces that form the curve. The same thing is seen in the quadruped: for as the spine in the back and loins lies horizontally, and the neck rises towards the perpendicular, there would be danger of dislocation, if the vertebræ of the neck rose suddenly and abruptly from the body: there is, therefore, at the lowest part of the neck a sweep or semicircle, formed by the junction of several vertebræ, to permit the head to be erected; a remarkable example of which is shown in the stag.

When a delicate piece of mechanism is contrived by the hands of man it may be locked up and preserved. But the most delicate textures of the living frame stand distinguished, above all, by this quality, that if they be not put to use, they very quickly degenerate. Not only is the faculty of action lost by inaction, as every one must be aware takes place in the functions of his own mind, and in the exercise of his senses, but the texture of the organs quickly degenerates. If by accident a limb should lose certain movements, the muscles, nerves, vessels, which Nature intended to be subservient to these motions, become, in a few weeks or months, so wasted, that they are hardly recognisable by the anatomist. If we apply this acknowledged principle to the spine, and take along with us that the texture of bone, cartilage, ligament, tendon, muscle, all the parts which enter into its structure, and are necessary to its perfection, however varying in solidity or composition, retain their perfection by being exercised, we shall readily perceive the effect of confinement, on young females. Without any positive disease, but from being over-educated in modes which require sedentary application, the spine becomes weak and loose in texture, and yields to the prevailing posture, whatever that may be. We mention this, because it is a principle, important, in every consideration, to each individual, and applicable to both body and mind.

The French philosophers have entertained the notion that the central parts of all animals are more permanent in their construction, whilst the extremities are subject to variety,—a theory, partly admitted by some eminent physiologists among ourselves, and which introduces obscurity and hypothesis into one of the most remarkable proofs of design. Dr. Roget, in his excellent 'Bridgewater Treatise,' has taken up this idea.

A spinal marrow belongs to the whole of the vertebrated class of animals; and the spinal marrow must be protected by bone: accordingly, as the principal use of the spine is permanent, so must its form be. Yet whenever there is a change in the action, or rather in the play of the spine, we find the vertebræ conformable. Thus, the motion of a fish through the water, results from a lateral movement of the tail and spine; but were the constituent bones formed like those of other animals of the same class, the lateral or transverse processes of the vertebræ would interfere with this motion: they are therefore removed, and in order to give strength to the chain of bones, the spinous processes are prolonged towards the back, and corresponding processes project towards the viscera. In the cetacea, as the whale and dolphin, &c., the position of the tail is reversed; it lies out horizontally; and the vertebræ correspond. These animals must rise to breathe the air, and their tails are thus provided to raise them easily to the surface; a proof, if any were wanted, that the spine, the very centre of the system, is accommodated to the main function of respiration.

The tail of animals is the prolongation of the spine. But it seems extraordinary that any one should make this the ground of an hypothesis, that when parts are repeated, they become more and more imperfect as they recede from the centre. It is however referred to in view, because the bones constituting the tail become smaller and rounder, and terminate in cartilage in which there is no bone. Is it not, on the contrary, obvious that the tail of animals is constituted for its proper purpose, firm towards the root, with muscles to play it in all directions, and less firm and more elastic towards the end, to carry

the brush? Can any thing be better adapted to such purposes? Would it be more perfect if there were vertebræ instead of round bones joined together? In short, corresponding as this part does with its uses, sometimes as a brush to curl round the animal and be a mantle for warmth, sometimes as a rudder in running, sometimes as a fan, and always reaching where the ear or tongue cannot reach—must all the obvious provisions be lost sight of in the consideration that animal bodies are constituted so imperfectly, that if a part like a vertebra be formed in the centre, repeated or prolonged, each link, as it recedes from the centre, must become less and less perfect, degenerating from what is presumed gratuitously to be its original form?—SIR CHARLES BELL.]

IV. The reciprocal enlargement and contraction of the *chest* to allow for the play of the lungs, depends upon a simple yet beautiful mechanical contrivance, referable to the structure of the bones which enclose it. The ribs are articulated to the back-bone, or rather to its side projections, *obliquely*; that is, in their natural position they bend or slope from the place of articulation downwards. But the basis upon which they rest at this end being fixed, the consequence of the obliquity, or the inclination downwards, is, that when they come to move, whatever pulls the ribs upwards, necessarily, at the same time, draws them out; and that, whilst the ribs are brought to a right angle with the spine behind, the sternum, or part of the chest to which they are attached in front, is thrust forward. The simple action, therefore, of the elevating muscles does the business; whereas, if the ribs had been articulated with the bodies of the vertebræ at right angles, the cavity of the thorax could never have been further enlarged by a change of their position. If each rib had been a rigid bone, articulated at both ends to fixed bases, the whole chest had been immovable. Keill has observed that the breast-bone, in an easy inspiration, is thrust out one tenth of an inch; and he calculates that this, added to what is gained to the space within the chest by the flattening or descent of the diaphragm,

leaves room for forty-two cubic inches of air to enter at every drawing-in of the breath. When there is a necessity for a deeper and more laborious inspiration, the enlargement of the capacity of the chest may be so increased by effort, as that the lungs may be distended with seventy or a hundred such cubic inches.* The thorax, says Schelhammer, forms a kind of bellows, such as never have been, nor probably will be, made by any artificer.

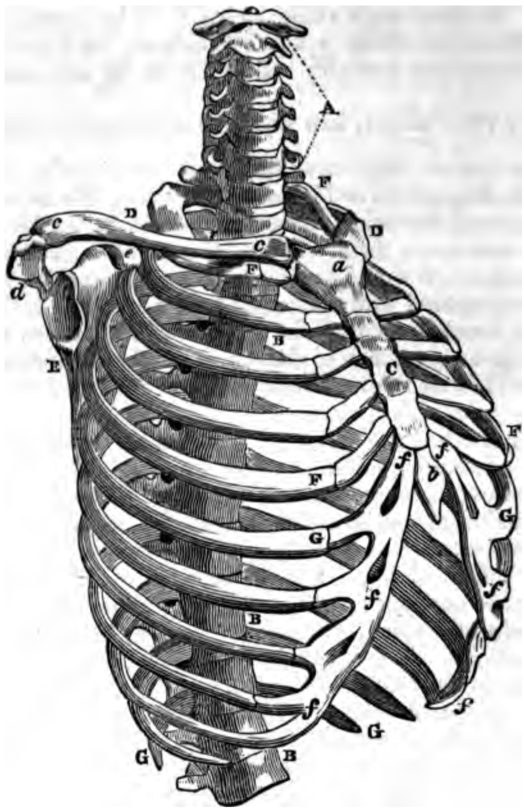
[OF THE THORAX, AND MECHANISM OF RESPIRATION.

Our author might have made more use of the thorax as affording proofs of his great argument. We have here represented the spine, breast-bone, and ribs, as the anatomist articulates them. Were he to make a skeleton in this fashion, it would be fragile in an extraordinary degree, compared with the natural body; and if the skeleton fell, it would inevitably be broken. Let us see, then, what gives protection to the bones in the natural body. The celebrated John Hunter was much engaged in showing by what means elasticity came in aid of the muscular power, both in the textures circulating the blood, and in those ministering to the play of the lungs. We may observe how the same principle conduces to the protection of the ribs, as well as assists their motion in respiration.

The anterior part of the rib, *f*, which ekes out the rib, F, G, and joins it to the breast-bone, C, is formed of elastic cartilage; and the rib having a free articulation behind to the spine, it results that each rib is possessed of elasticity. The anatomist making no proper substitute for this in the artificial skeleton, the bone breaks easily, like a piece of china. We have another proof, in the natural body, of the necessity for elasticity. We before observed that a child, rash and unsteady, is liable to a thousand accidents to which those of maturer years are not exposed. Now, during all the active years of life, the whole textures of the frame, and especially of the thorax, both bone and cartilage, possess elasticity, corresponding with the hazards to which youth is subject:

* Anat. p. 229.

in short, the child falls and suffers no injury; when an old man, striking his ribs upon the corner of the table, has them fractured. But let us observe the effect of elasticity in the act of respiration.



This drawing has been taken from an artificial skeleton, which is seldom articulated correctly. The ribs do not lie here in a natural position; or, if ever they were placed so in the living body, it could only be in violent inspiration, *when they* are raised to the very utmost.

The ribs do not move to accommodate themselves to the motions of the lungs, but by moving draw the lungs after them, and cause their expansion. The interstices of the ribs being filled up, and a septum closing the thorax below, the enlargement of the cavity permits the lungs to be expanded by the weight of the atmosphere, the air entering them through the windpipe. We at once see the importance of the motions of the ribs, for the expansion of the chest and the play of the lungs. Our author has, however, omitted an essential part of this interesting subject. He has shown that the oblique position of the ribs is necessary to inspiration, and that, by the rising of the anterior part of the rib, the breast-bone is thrust forwards and the cavity enlarged. But the rib has a double motion. It has a motion on its own axis. Suppose a line drawn through the two extremities of a rib, which would represent the string of a bow; that string is stationary, while the bow, representing the rib, revolves; thus the rib, by having its anterior extremity depressed and revolving as it is raised, enlarges the transverse diameter of the thorax, as well as the anterior diameter. In this action the cartilage in front is twisted; and the torsion of this elastic matter affects the muscular action in the manner following.

We have understood the act of respiration to be essential to life, and that the expansion of the chest dilates the lungs, gives freedom of circulation through them, and decarbonizes the blood. It is interesting, therefore, to see how a property of dead matter, elasticity, becomes a guard upon life. Every one must feel that it is easier to expire the air than to inspire it; and if we can imagine a person fainting, or in any mode in danger of death, (the very word expiring, in its common sense, implies that the last act of life is the expulsion of the breath,) if the elasticity tends to enlarge the chest, it must tend to the preservation of life, by restoring the circulation through the lungs. This is exactly what happens from the elastic structure of the whole compages of the chest. The elastic property preserves the chest in a middle state. The muscles of inspiration act against the elasticity: the muscles of *expiration also* act against it: the elasticity tends,

therefore, to maintain an intermediate state of dilatation of the thorax ; and accordingly, the lungs are preserved in a condition to perform their functions, for a certain period, at least, after the vital actions would have ceased through the muscles, had there been no such structure.

The great physiologist whom we have already mentioned, John Hunter, taught that when one part performed two functions, there was necessarily an imperfection. We have now the most suitable opportunity of controverting that position ; for this texture of the thorax is subservient to many different functions. There is no imperfection evinced in the organ of smelling, because, in order to draw in the odoriferous effluvia, and make them pass over the olfactory nerve, we use the lungs. Nor do we experience any material interference with respiration, because we enjoy the power of speech through an impulse given to the air in expiration. Further, let us attend to the form and expansion of the chest, as conducive to the motion and strength of the arm and hand. The motions of the superior extremity result from muscles which lie upon the chest ; and were it not for the expansion of the chest, from the contained atmospheric air, these muscles would not act with sufficient power, or a substitute must have been found, either of projecting bones, or of some solid texture, to afford lodgement and attachment to these muscles.

Then, again, considering man in his natural condition, the chances of life would run against him if he were incapable of floating upon water, or if the atmospheric air in his body were not anterior to his centre of gravity. The force of this argument will be understood when we remember, that the air contained within the lungs, after a man has made an inspiration, amounts to three hundred and thirty cubic inches.

Looking to the means of guarding life, nothing can be more important than the condition of the lungs, in respect to the atmospheric air within them. The sensibility, and the rapid contraction of the glottis, which is at the mouth of the respiratory tube, is for the purpose of arresting *any foreign* matter afloat in the atmosphere, which might

be drawn in by the stream of inspired air, and so reach the recesses of the lungs. But were this all, the office would be but half performed. The foreign body would be arrested; but how would it be expelled if it lodged? In common expiration the air is never expelled altogether from the lungs: there is enough retained to be propelled against this foreign body, and to eject it. And, but for this, the sensibility of the glottis, and the actions of the expiratory muscles, would be in vain; we should be suffocated by the slightest husk of seed, or subject to deep inflammation by the collection of foreign matter drawn into the air-tubes.

We may here observe, that the instinctive actions for the protection of the body are calculated, if we may say so, for the natural condition of man. The manufacturer is sometimes removed from that condition; and our invention must be taxed, not only to maintain the purity of the atmosphere in which he works, in a chemical sense, but to arrest, or convey away, the small portions of material which may be thrown off by the operations of the flax-dresser, for example, in heckling, or of the cutler, whose occupation it is to grind the steel after the instrument is forged, or of the stone-cutter, &c., and so to prevent those particles being inhaled. The length of the passages which lead to the lungs, the sensibility and muscular apparatus bestowed upon them, and the mucous secretions thrown into them, are the natural means by which foreign matter is arrested and thrown out. But in these artificial conditions of men, insoluble particles are continually floating in the atmosphere which they breathe; these are drawn in and lodge in the lungs, and irritate to disease.

The reader will find that the following extract, from a paper upon actions of the windpipe, illustrates the present subject.*

"We read that the trachea is formed of imperfect hoops of cartilages joined by membranes, and that it is flat on the back part for these reasons: that it may be a rigid and free tube for respiring the air; that it may ac-

* Philosophical Transactions.

commodate itself to the motions of the head and neck; and that it may yield in the act of swallowing to the distended œsophagus, and permit the morsel to descend. This is perfectly correct: but there is a grand omission. Whilst all admit that a copious secretion is poured into this passage, is not shown how the mucus is thrown off.

"There is a fine and very regular layer of muscular fibres on the back part of the trachea, exterior to the mucous coat, and which runs from the extremities of the cartilages of one side to those of the other. This transverse muscle is beautifully distinct in the horse.

"When a portion of the trachea is taken out, and every thing is dissected off but this muscle, the cartilages are preserved in their natural state; but the moment that the muscular fibres are cut across, the cartilages fly open. This muscle, then, is opposed to the elasticity of the cartilages of the trachea. By its action it diminishes the calibre of the tube, and by its relaxation the canal widens without the operation of an opponent muscle.

"The whole extent of the air-passages opens or expands during inspiration, and then the trachea is also more free; but in expiration, and especially in forcible expectoration and coughing, the trachea is diminished in width. The effect of this simple expedient is to free the passage of the accumulated secretion, which, without this, would be drawn in and gravitate towards the lungs. When the air is inspired, the trachea is wide, and the mucus is not urged downwards. When the air is expelled, the transverse muscle is in action, the calibre of the tube is diminished, the mucus occupies a larger proportion of the canal, the air is sent forth with a greater impetus than that with which it was inhaled, and the consequence is a gradual tendency of the sputa towards the top of the trachea. In the larynx the same principle holds; for as the opening of the glottis enlarges in inspiration, and is straitened in expiration, the sensible glottis, by inducing coughing, gets rid of its encumbrance. Without this change in the calibre of the trachea, the secretions could not reach the upper end of the passage, but would fall back upon the lungs.

"Experiments have been formerly made by M. Favier, which, although no such view as I now present was then in contemplation, prove how the action of the transverse muscle tends to expel foreign bodies. The trachea of a large dog being opened, it was attempted to thrust different substances into it during inspiration, but these were always sent out with impetus, and could not be retained. Why the dog could not be thus suffocated is apparent: the tube is furnished with this most salutary provision to secure the ready expulsion of all bodies accidentally inhaled—the air passes inwards by the side of the foreign body, but, in its passage outwards, the circumstances are changed by the diminished calibre of the canal, and the body, like a pellet filling up a tube, must be expelled by the breath."

We have, perhaps, pushed the inquiry far enough; and yet the interest might be increased by observing the manner in which the textures of the ribs are accommodated to variations in the mode of respiration, or to the necessity of the animal expressing the air from the lungs in diving. We have seen how the thorax is expanded in birds to the whole extent of the body, for obvious reasons; and the counterpart of that is presented where the animal, instead of being buoyant in the atmosphere, has to dive into the water and crawl at the bottom—not at great depths, but yet under water, in shallow pools and marshy places. The frog has no ribs; and its mode of respiration shows a complete change from that of animals which breathe with a diaphragm. It has the power of compressing its body, and expelling the air from the lungs; and were it not for this, the animal would remain on the surface of the water, as when cruel boys blow them up with a straw. The crocodile and other saurian reptiles, have their ribs accommodated so as to produce a similar effect, and for a similar purpose. Instead of the arched form of the ribs, which we have described as capable of a slight change of figure only, they have ribs composed of distinct pieces, and jointed in such a manner as to enable them to compress the chest into a smaller volume.

We have a sort of exposition of the uses, if not the

necessity, of respiration to the voice, in observing by what substitutes sound is produced, for example, in insects, which do not breathe by lungs. And, indeed, the same consideration suggests the inquiry as to the means by which the atmosphere is agitated, in the same class of animals, in subservience to the sense of smelling.

THE SUBJECT CONTINUED WITH REFERENCE TO THE CAPACITY OF THE CHEST, AND ITS CONDITION DURING BODILY EXERTION.

We must approach this part of our subject by the consideration of that law of fluids which appears, at first, so contradictory as to be called the "hydrostatic paradox."

Suppose a machine formed of two boards of equal diameter, and joined together by leather, nailed to their

margins, like a pair of bellows : a hole is made in the upper board, into which is inserted a tube. Now, if a person mount upon this apparatus when it is filled with water, and blow into the tube, he can raise the upper board, carrying himself upwards by the force of his own breath—indeed, by the power of his cheeks alone. It is on the same principle that, when a forcing-pump is let into a closed reservoir of water, it produces surprising effects. The piston of the hydraulic press being loaded with a weight of one pound, the same degree of pressure will be transmitted to every part of the surface of the reservoir that is given to the bottom of the tube, and the power of raising the upper lid will be multiplied in the proportion that its surface is larger than the diameter of the tube. Or, to state it conversely : suppose we had to raise the column of water in the tube by compressing the reservoir, it would require the weight of a pound on every portion of the superficies of the reservoir equal in extent to the base of the piston, before the water could be raised in the tube. If the apparatus which we have described were full of air instead of water, we should witness a similar effect ; for all fluids, whether elastic or not, press equally in all directions ; and this is the law on which the phenomenon depends. If we blow into the nozzle of a common pair of bellows, it is surprising what a weight of books we can heave up if laid upon its board.

Understanding, then, that the power of the hydraulic press, in raising the lid, depends on the size of the reservoir, and its relation to the tube ; and, again, that in pressing the fluid up through the tube, the pressure upon the sides of the reservoir must be the greater the larger the cavity, we can conceive how a glass-blower propels the air into his blow-pipe with great ease, if he blows with the contraction of the cheeks, the smaller cavity ; but with an exhausting effort, if he blows by the compression of the larger cavity, the chest. Dr. Young made a calculation, the result of which was, that, in propelling the air through a tube of the same calibre, a weight of four pounds operating upon a cavity of the size of the mouth

would be equal to the weight of seventy pounds pressing upon a cavity of the dimensions of the chest.*

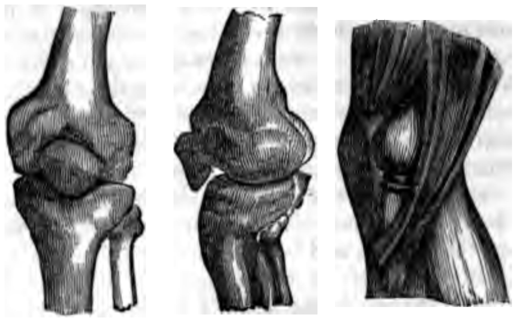
Let us see how beautifully this hydraulic principle is introduced to give strength in the common actions of the body. We have remarked, that the extension of the superficies of the thorax is necessary to the powerful action of the muscles which lie upon it; and these are the muscles of the arms. We must all have observed, too, that in preparation for a great effort, we draw the breath and expand the chest. The start into exertion, and of surprise, in man and animals, is this instinctive act. But unless there were some other means of preserving the lungs distended, the action of those muscles which should be thrown upon the arms, would be wasted in keeping the chest expanded. It is here, then, that the principle which we have noticed is brought into play. The chink of the glottis, which the reader has already understood to be the top of that tube which descends into the lungs,

* The action of one who uses the blow-pipe is rather curious. The mouth is distended with air, and the passage at the back of the mouth closed; the man breathes through the nostrils, but, from time to time, admits a portion of air into the mouth in expiration. The pressure into the blow-pipe is from the distension and consequent elasticity of the cheeks, occasionally assisted by the buccinator muscle, or trumpeter's muscle, so called because it compresses the distended cheeks. In this way the stream of air through the blow-pipe is kept up *uninterruptedly*, whilst the man breathes freely through his nostrils.

is closed by a muscle not weighing a thousandth part of the muscles which clothe the chest; and this little muscle controls them all. A sailor, leaning his breast over a yard-arm, and exerting every muscle on the rigging, gives a direction to the whole muscular system, and applies the muscles of respiration to the motions of the trunk and arms, through the influence of this small muscle, that is not capable of raising a thousandth part of the weight of his body: because this little muscle operates upon the chink of the glottis, and is capable of opposing the whole combined power of all the muscles of expiration. It closes the tube just in the same way that the man standing on the hydraulic bellows can with his lips support his whole weight. Thus it is, that the muscles which would else be engaged in dilating the chest, are permitted to give their power to the motions of the arms.

Some cruel experiments have been made, and, for whatever intended, they illustrate the necessity of closing the top of the windpipe during exertion. The windpipe of a dog was opened, which produced no defect until the animal was solicited by his master to leap across a ditch, when it fell into the water in the act of leaping; because the muscles, which should have given force to the fore-legs, lost their power by the sudden sinking of the chest. The experiment is sufficiently repugnant to our feelings; and I need not offend the reader by giving instances in further illustration, from what sometimes takes place in man.—SIR CHARLES BELL.]

V. The *patella*, or kneepan, is a curious little bone: in its form and office unlike any other bone in the body. It is circular; the size of a crown-piece; pretty thick; a little convex on both sides, and covered with a smooth cartilage. It lies upon the front of the knee: and the powerful tendons, by which the leg is brought forward, pass through it, (or rather it makes a part of their continuation,) from their origin in the thigh to their insertion in the tibia. It protects both the tendon and the joint from any injury which either might suffer, by the rubbing of one against the other, or by the pressure of unequal



[Three views of the knee-joints.]

surfaces. It also gives to the tendons a very considerable mechanical advantage, by altering the line of their direction, and by advancing it further out from the centre of motion ; and this upon the principles of the resolution of force, upon which principles all machinery is founded. These are its uses. But what is most observable in it is, that it appears to be supplemental, as it were, to the frame : added, as it should almost seem, afterward ; not quite necessary, but very convenient. It is separate from the other bones : that is, it is not connected with any other bones by the common mode of union. It is soft, or hardly formed, in infancy ; and produced by an ossification, of the inception, or progress of which no account can be given from the structure or exercise of the part.

VI. The *shoulder-blade* is, in some material respects, a very singular bone ; appearing to be made so expressly for its own purpose, and so independently of every other reason. In such quadrupeds as have no collar-bones, which are by far the greater number, the shoulder-blade has no bony communication with the trunk, either by a joint, or process, or in any other way. It does not grow to, or out of, any other bone of the trunk. It does not apply to any other bone of the trunk—(I know not whether this be true of any second bone in the body, ex-

cept perhaps the os hyoïdes :) in strictness, it forms no part of the skeleton. It is bedded in the flesh, attached only to the muscles. It is no other than a foundation bone for the arm, laid in, separate as it were, and distinct, from the general ossification. The lower limbs connect themselves at the hip with bones which form part of the skeleton; but this connexion, in the upper limbs, being wanting, a basis, whereupon the arm might be articulated, was to be supplied by a detached ossification for the purpose.[18]

OF THE JOINTS.

I. The above are a few examples of bones made remarkable by their configuration; but to almost all the bones belong *joints*; and in these, still more clearly than in the form or shape of the bones themselves, are seen both contrivance and contriving wisdom. Every joint is a curiosity, and is also strictly mechanical. There is the hinge-joint and the mortice-and-tenon joint; each as manifestly such, and as accurately defined, as any which can be produced out of a cabinet-maker's shop; and one

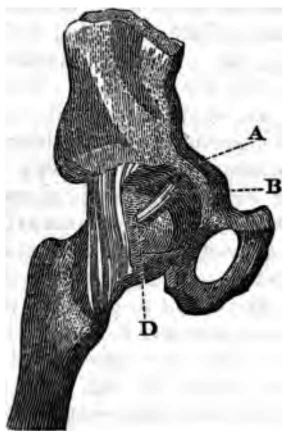
[18] The shoulder-blade undergoes many changes, as we view it in comparative anatomy. That bone which we feel running across the upper part of the chest and lower part of the neck, the collar-bone, is properly a process of the shoulder-blade. Its purpose is to hold the shoulders apart, and to give strength to the arms, by throwing upon the arm the action of the muscles of the chest. Accordingly, we find it in climbing animals, in those which require to swing themselves by the upper extremities, as the monkeys; but in animals that have a solid hoof, which implies that the anterior extremity is for the particular purpose of running or bounding upon the ground, not only is there no occasion for that variety in the motions of the extremity, which is produced by the introduction of this bone into the skeleton of the arm, but it would be injurious—it would deprive the animal of that elasticity with which it alights upon the ground. Where there is no clavicle—in the horse and deer, for example, the shoulder-blade, or scapula, is attached to the trunk by muscles alone. Hence, when the animal makes a leap, it comes down upon the forelegs with an elastic rebound, the trunk hanging upon the muscles, the muscles supported by the scapula, and the scapula sustained upon the bones of the extremity. There is no solid substance to receive the shock. Were the collar-bone introduced here, it would be snapped across by the percussion, as happens to a man when he is thrown upon his shoulder.—*Eng. Ed.*

or the other prevails, as either is adapted to the motion which is wanted—*e. g.*, a mortice and tenon, or ball and socket joint, is not required at the knee, the leg standing in need only of a motion backward and forward in the same plane, for which a hinge-joint is sufficient; a mortice and tenon, or ball and socket joint, is wanted at the hip, that not only the progressive step may be provided for, but the interval between the limbs may be enlarged or contracted at pleasure. Now observe what would have been the inconveniency—*i. e.*, both the superfluity and the defect of articulation, if the case had been inverted: if the ball and socket joint had been at the knee, and the hinge-joint at the hip. The thighs must have been kept constantly together, and the legs have been loose and straddling. There would have been no use, that we know of, in being able to turn the calves of the legs before; and there would have been great confinement by restraining the motion of the thighs to one plane. The disadvantage would not have been less, if the joints at the hip and the knee had been both of the same sort; both balls and sockets, or both hinges; yet why, independently of utility, and of a Creator who consulted that utility, should the same bone (the thigh-bone) be rounded at one end, and channelled at the other?

The *hinge-joint* is not formed by a bolt passing through the two parts of the hinge, and thus keeping them in their places, but by a different expedient. A strong, tough, parchment-like membrane, rising from the receiving bones, and inserted all round the received bones, a little below their heads, encloses the joint on every side. This membrane ties, confines, and holds the ends of the bones together, keeping the corresponding parts of the joints—*i. e.*, the relative convexities and concavities—in close application to each other.

For the *ball and socket joint*, besides the membrane already described, there is in some important joints, as an additional security, a short, strong, yet flexible ligament, inserted by one end into the head of the ball, by the other into the bottom of the cup, which ligament keeps the two parts of the joint so firmly in their place, that none of the

motions which the limb naturally performs, none of the ierks and twists to which it is ordinarily liable, nothing less indeed than the utmost and the most unnatural violence, can pull them asunder. It is hardly imaginable, how great a force is necessary, even to stretch, still more to break, this ligament: yet so flexible is it, as to oppose no impediment to the suppleness of the joint. By its situation, also, it is inaccessible to injury from sharp edges. As it cannot be ruptured, (such is its strength,) so it cannot be cut, except by an accident which would sever the limb.



[A, the cup-shaped cavity of the hip-joint; B, the strong round ligament, fastening the head of the thigh-bone, D, to the cavity of the joint.—AM. ED.]

If I had been permitted to frame a proof of contrivance, such as might satisfy the most distrustful inquirer, I know not whether I could have chosen an example of mechanism more unequivocal, or more free from objection, than this ligament. Nothing can be more mechanical; nothing, however subservient to the safety, less capable of being generated by the action of the joint. I would particularly solicit the reader's attention to this provision, as it is found in the head of the *thigh-bone*: to its strength, *its structure, and its use.* It is an instance upon which I lay my

hand. One single fact, weighed by a mind in earnest, leaves oftentimes the deepest impression. For the purpose of addressing different understandings and different apprehensions—for the purpose of sentiment—for the purpose of exciting admiration of the Creator's works, we diversify our views, we multiply our examples: but, for the purpose of strict argument, one clear instance is sufficient; and not only sufficient, but capable perhaps of generating a firmer assurance than what can arise from a divided attention.[19]

The *ginglymus*, or hinge-joint, does not, it is manifest, admit of a ligament of the same kind with that of the ball and socket joint; but it is always fortified by the species of ligament of which it does admit. The strong, firm, investing membrane, above described, accompanies it in every part; and in particular joints, this membrane, which is properly a ligament, is considerably stronger on the sides than either before or behind, in order that the convexities may play true in their concavities, and not be subject to slip sideways, which is the chief danger; for the muscular tendons generally restrain the parts from going further than they ought to go in the plane of their motion. In the *knee*, which is a joint of this form, and of great importance, there are superadded to the common provisions for the stability of the joint, two strong ligaments, which cross each other—and cross each other in such a manner, as to secure the joint from being displaced in any assignable direction.

"I think," says Cheselden, "that the knee cannot be completely dislocated without breaking the *cross* ligaments."* We can hardly help comparing this with the binding up of a fracture, where the fillet is almost wholly strapped across, for the sake of giving firmness and strength to the bandage.

[19] This ligament is absent in the orang-outang; and in the lower extremity of this animal, there are other points of resemblance to the structure of the arm; and certainly the use of the hinder extremity corresponds with this structure, since he grasps and swings equally well with either extremity.—ENG. ED.

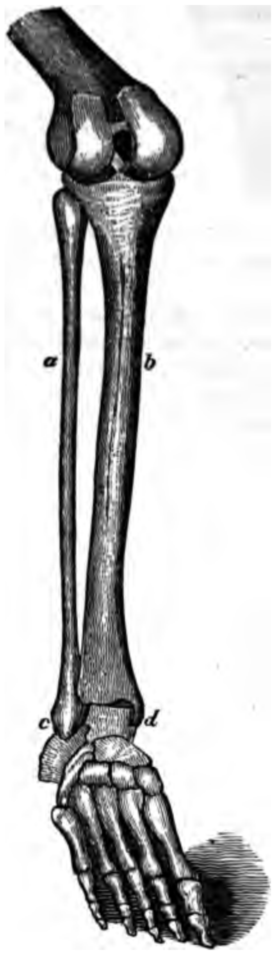
* *Ches.* Anat. ed. 7th, p. 45

[This cut shows the surfaces of the bones constituting the knee-joint, with its strong cross ligaments.—AM. ED.]

Another no less important joint, and that also of the ginglymus sort, is the *ankle;* yet, though important, (in order, perhaps, to preserve the symmetry and lightness of the limb,) *small*, and, on that account, more liable to injury. Now this joint is strengthened, *i. e.*, is defended from dislocation, by two remarkable processes or prolongations of the bones of the leg, which processes form the protuberances that we call the inner and outer ankle. It is part of each bone going down lower than the other part, and thereby overlapping the joint: so that if the joint be in danger of slipping outward, it is curbed by the inner projection, *i. e.*, that of the tibia; if inward, by the outer projection, *i. e.*, that of the fibula. Between both, it is locked in its position. I know no account that can be given of this structure, except its utility.[20] Why should the tibia

[20] It is surprising, that among so many instances, our author should omit to notice the perfection in the ankle-joint. When we stand resting upon the foot, the joint is firm, and yields neither to the inside nor the outside; but when we move the foot forward and point the toe in making the step, such is the happy form of the bones, that the foot is in this position thrown quite loose. The object here certainly is, that in walking on the irregular ground, we may have a freedom in directing the foot so as to plant it securely. But before the weight of the body is brought perpendicularly over the foot, there is no danger to the joint, because there is no strain upon it. Just in proportion as the advancing body begins to bear upon it do the bones take that position, in which they are as firm as in the knee-joint itself, admitting only the motion of a hinge.—ENG. ED.

terminate, at its lower extremity, with a double end, and the fibula the same—but to barricade the joint on both sides by a



[*a*, the fibula, or small bone of the leg, extending down to guard the ankle on the outside at *c* ; *b*, the tibia or large bone of the leg, extending down to guard the ankle-joint on the inner side at *d*.—AM. ED.]

continuation of part of the thickest of the bone over it? The *joint at the shoulder*, compared with the joint at the hip,

though both ball and socket joints, discovers a difference in their form and proportions, well suited to the different offices which the limbs have to execute. The cup or socket at the shoulder is much shallower and flatter than it is at the hip, and is also in part formed of cartilage set round the rim of the cup. The socket, into which the head of the thigh-bone is inserted, is deeper, and made of more solid materials. This agrees with the duties assigned to each part. The arm is an instrument of motion, principally, if not solely. Accordingly, the shallowness of the socket at the shoulder, and the yieldingness of the cartilaginous substance with which its edge is set round, and which in fact composes a considerable part of its concavity, are excellently adapted for the allowance of a free motion, and a wide range, both which the arm wants. Whereas, the lower limb forming a part of the column of the body—having to support the body, as well as to be the means of its locomotion—firmness was to be consulted as well as action. With a capacity for motion, in all directions indeed, as at the shoulder, but not in any direction to the same extent as in the arm, was to be united stability, or resistance to dislocation. Hence the deeper excavation of the socket, and the presence of a less proportion of cartilage upon the edge.

The suppleness and pliability of the joints we every moment experience; and the *firmness* of animal articulation, the property we have hitherto been considering, may be judged of from this single observation, that, at any given moment of time, there are millions of animal joints in complete repair and use, for one that is dislocated; and this, notwithstanding the contortions and wrenches to which the limbs of animals are continually subject.

II. The *joints*, or rather the ends of the bones which form them, display also, in their configuration, another use. The nerves, blood-vessels, and tendons, which are necessary to the life, or for the motion, of the limbs, must, it is evident, in their way from the trunk of the body to the place of their destination, travel over the movable joints; and it is no less evident that, in this part of their

course, they will have, from sudden motions, and from abrupt changes of curvature, to encounter the danger of compression, attrition, or laceration. To guard fibres so tender against consequences so injurious, their path is in those parts protected with peculiar care; and that by a provision in the figure of the bones themselves. The nerves which supply the *fore-arm*, especially the inferior cubital nerves, are at the elbow conducted, by a kind of covered way, between the condyles, or rather under the inner extuberances of the bone which composes the upper part of the arm.* At the *knee*, the extremity of the thigh-bone is divided by a sinus, or cliff, into two heads or protuberances; and these heads on the back-part stand out beyond the cylinder of the bone. Through the hollow which lies between the hind-parts of these two heads—that is to say, under the ham, between the ham-strings, and within the concave recess of the bone formed by the extuberances on each side—in a word, along a defile, between rocks, pass the great vessels and nerves which go to the leg.† Who led these vessels by a road so defended and secured? In the joint at the *shoulder*, in the edge of the cup which receives the head of the bone, is a *notch*, which is joined or covered at the top with a ligament. Through this hole, thus guarded, the blood-vessels steal to their destination in the arm, instead of mounting over the edge of the concavity.‡

III. In all joints, the end of the bones, which work against each other, are tipped with *gristle*. In the ball and socket joint, the cup is lined and the ball capped with it. The smooth surface, the elastic and unfriable nature of cartilage, render it of all substances the most proper for the place and purpose. I should, therefore, have pointed this out amongst the foremost of the provisions which have been made in the joints for the facilitating of their action, had it not been alleged, that cartilage in truth is only nascent or imperfect bone; and that the bone in these places is kept soft and imperfect, in consequence of a more complete and rigid ossification being prevented

* Ches. Anat. p. 255, ed. 7.

† Ibid. p. 35.

‡ Ibid. p. 30.

from taking place by the continual motion and rubbing of the surfaces: which being so, what we represent as a designed advantage is an unavoidable effect. I am far from being convinced that this is a true account of the fact; or that, if it were so, it answers the argument.[21] To me the surmounting of the bones with gristle looks more like a plating with a different metal, than like the same metal kept in a different state by the action to which it is exposed. At all events, we have a great particular benefit, though arising from a general constitution; but this last not being quite what my argument requires, lest I should seem by applying the instance to overrate its value, I have thought it fair to state the question which attends it.

IV. In some joints, very particularly in the knees, there are loose cartilages or gristles between the bones, and within the joint, so that the ends of the bones, instead of working upon one another, work upon the intermediate cartilages. Cheselden has observed,* that the contrivance of a loose ring is practised by mechanics where the friction of the joints of any of their machines is great, as between the parts of crook-hinges of large gates, or under the head of the male screw of large vices. The cartilages of which we speak have very much of the form of these rings. The comparison, moreover, shows the reason why we find them in the knees rather than in other joints. It is an expedient, we have seen, which a mechanic resorts to only when some strong and heavy work is to be done. So here the thigh-bone has to achieve its motion at the knee, with the whole weight of the body pressing upon it, and often, as

[21] As the Archdeacon had been a pupil of Dr. William Hunter's, which we gather from the tenor of many of his observations, it is surprising that he has not spoken with more decision upon the point. The cartilage, which is the substitute for the bone in infancy, is very different from that which tips the ends of the articulating extremities of the bones. In a valuable paper of Dr. Hunter's, it is shown that this articulating cartilage consists of fibres, placed together like the hairs of a brush, but more compactly, and perpendicularly to the ends of the bones; and that on this arrangement chiefly depends the elasticity of the material. Its use is best proved by what takes place when it is deficient: for then the articulation creaks like an old hinge, and the patient suffers aches.—ENG. ED.

* Ches. Anat., *p. 13, ed. 7.*

in rising from our seat, with the whole weight of the body to lift. It should seem also, from Cheselden's account, that the slipping and sliding of the loose cartilages, though it be probably a small and obscure change, humored the motion at the end of the thigh-bone, under the particular configuration which was necessary to be given to it for the commodious action of the tendons (and which configuration requires what he calls a variable socket, that is, a concavity, the lines of which assume a different curvature in different inclinations of the bones.)[22]

V. We have now done with the configuration; but there is also in the joints, and that common to them all, another exquisite provision manifestly adapted to their use, and concerning which there can, I think, be no dispute, namely, the regular supply of a *mucilage*, more emollient and slippery than oil itself, which is constantly softening and lubricating the parts that rub upon each other, and thereby diminishing the effect of attrition in the highest possible degree. For the continual secretion of this important liniment and for the feeding of the cavities of the joint with it, glands are fixed near each joint, the excretory ducts of which glands, dripping with their balsamic contents, hang loose like fringes within the cavity of the joints. A late improvement in what are called friction wheels, which consists of a mechanism so ordered as to be regularly dropping oil into a box which encloses the axis, the nave, and certain balls upon which the nave revolves, may be said,

[22] This is not explained with our author's usual clearness. The lower head of the thigh-bone, which rests upon the shin-bone or *tibia*, is not the segment of a regular circle. When we stand with the knees straight, the thigh-bone rests with a broad surface, and the convexity is principally on the back part. Such an irregularity would make a very imperfect and jarring hinge-joint on any configuration that could be given to the corresponding surface of the tibia. Therefore these cartilages intervene; and, being possessed of considerable elasticity, and so connected with the bone as to shift their place a little, they accommodate themselves, whether the flatter end or the more convex part of the articulating surface of the bone be presented to them; and there is this advantage, that, in standing, when the weight on the joint is greatest, the thigh-bone has a more extensive, and consequently a more secure basis, at the same time that the motion of the joint as a hinge is perfect.—ENG. ED.

in some sort, to represent the contrivance in the animal joint, with this superiority, however, on the part of the joint, viz., that here the oil is not only dropped, but *made*.

In considering the joints, there is nothing, perhaps, which ought to move our gratitude more than the reflection, *how well they wear*. A limb shall swing upon its hinge, or play in its socket, many hundred times in an hour, for sixty years together, without diminution of its agility; which is a long time for any thing to last—for any thing so much worked and exercised as the joints are. This durability I should attribute in part to the provision which is made for the preventing of wear and tear, first, by the polish of the cartilaginous surfaces; secondly, by the healing lubrication of the mucilage, and, in part, to that astonishing property of animal constitutions, assimilation, by which, in every portion of the body, let it consist of what it will, substance is restored, and waste repaired.[23]

Movable joints, I think, compose the curiosity of bones; but their union, even where no motion is intended or wanted, carries marks of mechanism and of mechanical wisdom. The teeth, especially the front teeth, are one bone fixed

[23] We may here take a practical illustration. We have said that exercise is necessary to the perfection of a joint. Suppose the knee-joint to be inflamed: it is of course kept in perfect rest, because motion produces pain. This absolute rest, joined with inflammation, alters all the textures; the bone becomes light and spongy; the cartilage is absorbed; the ligaments which ought to hold the bones together become loose and relaxed; and what the surgeon calls consecutive dislocation may take place—that is, the bones will actually shift their place, from the defect of those attachments which ought to keep them together. Now, let us suppose the inflammation to have subsided: by due attention all may be restored; and by no other mode than moving the joint—the only precaution necessary being, that it shall be moved with a care and gentleness corresponding to its weakened condition. By this simple means the ligaments will acquire firmness, the cartilages smoothness, and the *synovia*, or lubricating mucilage, will be again poured out: from all which we see, that in the living animal textures, wear and tear do not take place upon continued motion; but, on the contrary, that exercise is made the stimulus to improvement. All other proofs of design, as adjustment, relation, compensation, prospective contrivance, are weak in comparison with this.—ENG. ED.

in another, like a peg driven into a board. The sutures of the skull are like the edges of two saws, clapped together in such a manner as that the teeth of one enter the intervals of the other. We have sometimes one bone lapping over another, and planed down at the edges; sometimes, also, the thin lamella of one bone received into the narrow furrow of another. In all which varieties, we seem to discover the same design, viz., firmness of juncture, without clumsiness in the seam.

[DESIGN OR MECHANICAL CONTRIVANCE, AS EXHIBITED IN THE BONES OF THE HEAD AND THEIR JOININGS.

The more important the part is to life, the more vital the organ, we find the texture or fabric which protects it the more perfect. The human skull presents us with many curious proofs that the forces or injuries to which it is exposed are calculated and provided against. But we shall take our first examples from the skulls of animals; and here we see that the brain is not covered in the same manner in all, but that in each variety there is a provision against the forces to which the skull is subjected. The skull of a dog is hardly in any respect like the skull of a ram; the bones of the former are thin; the line of union, which is called the *suture*, is simple; it is not provided to withstand percussion: but in the latter animal, there is reared over the proper brain-case a series of arched cells, of strong bone, and each bone is joined to another by a line, serrated, deep, and regular; the mechanical strength of the union always corresponding with the strength of the bones; and the whole being formed into a base suited for the support of the horns, and calculated to sustain the shock when the animal butts with the whole weight and strength.

We might contrast the skull of the ram or goat with that of the tiger, where the strength is in its jaws. This animal, too, has the brain-case small, and, as it were, buried in the head; but the jaws, instead of being spongy bones, as in man, are dense and strong to sustain the teeth; for what would avail these teeth, long and sharp and

strong, could they be twisted from their socket? and what would avail the strength of the jaws, and length and depth

The engraving represents the irregular line of union of the bones of the skull as seen on the outer surface.

of the teeth, were not the proper skull surrounded with spines, and arches of bone dense and strong enough to give attachment to the muscles of the jaws? Thus, in the carnivorous animal, the strength of the bony textures of the head is all concentrated in the jaws of the animal, and corresponds with its instinct to hold and rend its prey.

But when the lion or the tiger have struck down their prey, and have gorged themselves and sought their dens, and when the lesser carnivorous animals have cleared the bones—there remains a rich repast which they cannot reach; then comes the hyæna, which cracks the bones, and feeds upon the marrow.

Of all the skulls that can be collected in a museum, the jaws and teeth of the hyæna exhibit the most extraordinary strength; the bones having a clumsy form and dense texture quite peculiar, and suited for the socketing of the strong conical teeth.

We see, therefore, that the fabric of the head, taken as a whole, bears a certain resemblance in all classes of animals; but, though built upon the same general plan, the supports are given to fortify the points which bear the shock.

By such more obvious instances of adaptation we are led to inquire whether any similar adjustment of the resisting property of the bone is to be found in the human head. We must carry this along with us in our inquiry,

that a shock or vibration, going through the great mass of the human brain, proves more immediately destructive of the faculties, than the wound which penetrates the substance without a concussion. When we contemplate the condition of a child, its fearlessness, its restless activity, the falls and knocks it gets, we must perceive that were not the textures of the bones and the brain adjusted, the child when it fell must have lain insensible, instead of rising and crying more from terror than the sense of injury.

We may contrast this condition of the child with that of an old man losing his balance and falling on his head, who lies insensible from the shock. Is it not apparent that there is here a calculation of the accidents of life, and a provision against them, which yet leaves us threatened with danger, and, therefore, on our guard?

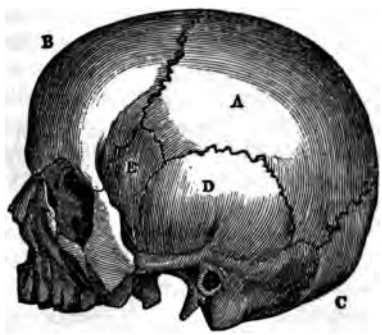
The difference in the textures of youth and age are instructive as to the causes of the diversity. The brain of the old man is firm; the vibration injures its fibre. The brain of the child is soft, and in infancy it may be moulded to any shape. Then, again, the texture of the bone is entirely different, and hardly like the same substance. It is thin and pliant in the child, actually dimpled by a blow; whilst in age it is brittle from its density, and the vibration of the blow runs round it; or if it be broken, it is like a piece of sharp glass entering the tender parts beneath.

Much more than will stand inquiry has been said of the forms of the head, in reference to the contained organs; but there is a simple demonstration which should precede all this: the forms of the skull bear a relation to pressure and injury from without, and the parts most exposed are most protected. A man falling backwards has the back of his head exposed to injury; and the examination and section of the bone at this part shows how Nature has strengthened it, by giving it greater thickness and prominence, and by groining it within. We say groining it; for there is nothing more resembling the strong groinings or arches of the ground-story of a great building, than the ridges of the skull at this part of its base, which

cross at a centre corresponding with the prominence of the occiput.

In front, the form of the skull exhibits a provision not less distinct in its object. The parts of the forehead which are most prominent and exposed exhibit, on their section, a thicker and denser bone; whilst the lower part of the forehead is formed of cells or sinuses, which, throwing off the outer wall of the skull from the surface of the brain, still more effectually protects it.

A person tumbling sideways pitches on the shoulder, and the convexity of the head comes to the ground precisely on that point (the centre of the parietal bone) where the bone is thickest and most dense.

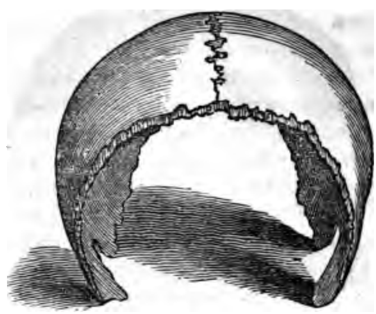


A. The *parietal* bone.
B. The *frontal* bone.
C. The *occipital* bone.
D. The *temporal* bone.
E. The *sphenoid* bone.

It is, on the whole, impossible to study the forms of the head without acknowledging that the shape, thickness, and texture of the skull have reference to the liability to pressure and blows from without.

To take a further example:—It seems very natural, in carrying a burden, to poise it on the head. Now, whether we take the carpentry (called a *centering*) on which the

stones of the arch of a bridge are laid in building it, or the arch of stone, or a dome—(for with all these the bones of the head may be aptly compared)—there has been nothing ever contrived so perfect as the joining of the bones of the head to resist both pressure above, and straining at the sides. And if, on this subject, we solicit the reader's attention more particularly to these joinings, it is because, in books merely anatomical, they are apt to be treated like things of accident, and described as the running of the fibres of one bone into another, the necessary consequence of their mode of growth; or the accidental effect of the pressure of the muscle; whereas, on the contrary, the finest tools of the carpenter could make nothing so perfect or so demonstrative of design.



The figure represents the two parietal bones—forming an arch, or a surmounted dome.

These provisions would surely have met with earlier attention had men contemplated, in a true view, the object of the animal frame-work; which is not to give absolute safety against inordinate violence, but to balance the chances of life,—leaving us still under the conviction, that pain and injury follow violence: so that our experience of the injury, and our fear of pain, whilst they are the principal protection to life, lay the foundation of important moral qualities in our nature.

OF THE JOINTS.

In comparing the skeleton with carpentry, or any thing artificial that admits of comparison with it, we remark that, in the bones, there is not a straight line, or regular form, whether they serve as a shaft, axle, or lever; while, in the other, every part is levelled and squared, or formed according to some geometrical curve. This would lead a superficial thinker to conclude, that the bones were formed irregularly, or without reference to principle; but the consideration of by Whom formed, leads to a review; and a deeper examination brings with it the conviction that the curves, spines, and protuberances of the bones are formed with a relation to the weight which they bear, and the thrusts and twists to which they are subjected, in the different motions of the body.

If we observe the various postures of a man at any manual labor, or under a weight, or running, or leaping, or wrestling, we shall be convinced that no carpentry of the bones, formed upon geometrical lines or curves, could suit all this variety of motion. No splicing, dovetailing, cogging, or any of all the various shapes into which the carpenter or joiner cuts his material, could enable them to withstand the motions of the body, where it is so utterly impossible to estimate the forces, or to calculate upon the variety in the motion.

That the varieties in the forms of the bones are not irregular, nor accidental, but are related to the motions to be performed, is apparent in the close examination of the human skeleton, and still more clearly evinced by comparative anatomy.

The shapes of the bones, are very closely related to the motions to be performed by the different joints. Let us observe the enlargement of the diameter of the bone at an articulation. This expansion of the articulated surface of the bone gives power to the binding ligaments, by removing them from the centre of motion; and by the increase of surface and additional strength of ligament, the danger of dislocation is much diminished. The fric-

tion of two bodies whose surfaces move upon one another is not increased by the extent of surface, the pressure remaining the same. Hence the enlargement of the surfaces of the joint is attended with greater security, without there being additional friction. But, for the most part, the surfaces of the bones, instead of sliding upon one another, have a rounded form, and roll upon each other. Now the friction, in this case, depends upon the diameter of the body which rolls, and is small in proportion as the diameter of that body is great, the weight being the same. By this we see that the large bones forming the knee-joint, for example, have every advantage of greater strength without increased friction.

Our author has perhaps dwelt sufficiently on the smoothness given to the articulating surfaces of the bones, by the cartilages and the synovial or lubricating fluid, vulgarly called joint-oil, (and ignorantly so called;) and after these general observations, in order fully to comprehend the fine adjustment of each bone in its articulation, we should require to go minutely into the anatomy. Then we should find, with how curious a mechanical adaptation the motions are permitted in the prescribed direction, and checked in every other. We should be called to observe, also, how the motions of one joint are related to those of another; and how, by the combination of joints, each of which is securely checked and strengthened, there is a facility and extent of motion produced by their combination: for example, in the arm and hand, where the motions are free, and varied in every possible direction.

It is interesting to see how the joints of the lower extremities are modified in man, in comparison with those of the upper. We have elsewhere remarked, that the bones of the human pelvis, thigh, and leg exceed those of all other animals in relative size, which shows a provision for the erect position of man. The same is evinced in the form of the joints, as the ankle, knee, and hip; for whilst their combinations give every necessary degree of motion consistent with security, there is a happy provision, producing at once firmness and mobility. That *is to say*, when the limb is thrown forward in walking or

running, it is loose, and capable of being freely directed; so that we plant it with every convenience to the irregularity of ground: but when the body is carried forward to be perpendicular over that limb, it acquires, by the curious adjustment of the bones, a firmness equal to that of a post. Again, when the body is still further thrown forward, and the limb is disencumbered of the weight of the body, the joints are let loose so as to be bent easily, and to obey the action of the muscles.—SIR CHARLES BELL.]

CHAPTER IX.

OF THE MUSCLES.

MUSCLES, with their tendons, are the instruments by which animal motion is performed. It will be our business to point out instances in which, and properties with respect to which, the disposition of these muscles is as strictly mechanical as that of the wires and strings of a puppet.

I. We may observe, what I believe is universal, an exact relation between the joint and the muscles which move it. Whatever motion the joint, by its mechanical construction, is capable of performing, that motion the annexed muscles, by their position, are capable of producing. For example, if there be, as at the knee and elbow, a hinge-joint, capable of motion only in the same plane, the leaders, as they are called, *i. e.*, the muscular tendons, are placed in directions parallel to the bone, so as, by the contraction or relaxation of the muscles to which they belong, to produce that motion and no other. If these joints were capable of a freer motion, there are no muscles to produce it. Whereas, at the shoulder and the hip, where the ball-and-socket joint allows, by its construction, of a rotatory or sweeping motion, tendons are placed in such a position, and pull in such a direction, as to produce the motion of which the joint admits. For

instance, the sartorius or tailor's muscle, rising from the spine, running diagonally across the thigh, and taking hold of the inside of the main bone of the leg a little below the knee, enables us, by its contraction, to throw one leg and thigh over the other, giving effect, at the same time, to the ball-and-socket joint at the hip, and the hinge-joint at the knee. There is, as we have seen, a specific mechanism in the bones for the rotatory motions of the head and hands: there is, also, in the oblique direction of the muscles belonging to them, a specific provision for the putting of this mechanism of the bones into action. And mark the consent of uses: the oblique muscles would have been inefficient without that particular articulation; that particular articulation would have been lost without the oblique muscles. It may be proper, however, to observe, with respect to the *head*, although I think it does not vary the case, that its oblique motions and inclinations are often motions in a *diagonal*, produced by the joint action of muscles lying in straight, directions. But whether the pull be single or combined, the articulation is always such, as to be capable of obeying the action of the muscles. The oblique muscles attached to the head are likewise so disposed, as to be capable of steadying the globe as well as of moving it. The head of a new-born infant is often obliged to be filleted up. After death, the head drops and rolls in every direction. So that it is by the equilibre of the muscles, by the aid of a considerable and equipollent muscular force in constant exertion, that the head maintains its erect posture. The muscles here supply, what would otherwise be a great defect in the articulation; for the joint in the neck, although admirably adapted to the motion of the head, is insufficient for its support. It is not only by the means of a most curious structure of the bones that a man turns his head, but by virtue of an adjusted muscular power that he even holds it up.

As another example of what we are illustrating, viz., conformity of use between the bones and the muscles, it has been observed of the different vertebræ, that their *processes* are exactly proportioned to the quantity of mo-

tion which the other bones allow of, and which the respective muscles are capable of producing.

II. A muscle acts only by contraction. Its force is exerted in no other way. When the exertion ceases, it relaxes itself, that is, it returns by relaxation to its former state, but without energy.[24] This is the nature of the muscular fibre; and being so, it is evident that the reciprocal *energetic* motion of the limbs, by which we mean motion *with force* in opposite directions, can only be produced by the instrumentality of opposite or antagonist muscles—of flexors and extensors answering to each other. For instance, the biceps and brachialis *internus* muscles, placed in the front part of the upper arm, by their contraction bend the elbow, and with such degree of force as the case requires, or the strength admits of. The relaxation of these muscles, after the effort, would merely let the fore-arm drop down. For the *back stroke*, therefore, and that the arm may not only bend at the elbow, but also extend and straighten itself with force, other muscles, the longus and brevis brachialis *externus*, and the anconæus, placed on the hinder part of the arms, by their contractile twitch, fetch back the fore-arm into a straight line with the cubit, with no less force than that with which it was bent out of it. The same thing obtains

[24] Excellently well as this is put, there is something more admirable still in the condition of the muscular system. With respect to the support of the head, as mentioned in the preceding page,—and the instance embraces, of course, the erect position of the body as well as the equable poising of the head,—the most extraordinary part of the phenomenon is this, that we are sensible of the slightest inclination of the body or of any member, although it would be difficult to say, to what order of acknowledged sensations this belongs. Not only do we feel every degree of inclination from the perpendicular in the poising of the body, but we act upon it with the most minute correspondence of the muscles. The muscles are antagonists certainly, but there is a fine combination and adjustment in their action, which is not illustrated by the two sawyers dividing a log of wood. The muscle, having finished what we call its action or contraction, is not in the condition of a loose rope, but, on the contrary, there is always a perfect balance of action preserved between the extent of relaxation of the one class of muscles, and the contraction of the other; and there is a tone in both by which the limb may be sustained in any posture that is willed. —*Eng. Ed.*

in all the limbs, and in every movable part of the body. A finger is not bent and straightened, without the *contraction* of two muscles taking place. It is evident, therefore, that the animal functions require that particular disposition of the muscles, which we describe by the name of antagonist muscles. And they are accordingly so disposed. Every muscle is provided with an adversary. They act like two sawyers in a pit, by an opposite pull; and nothing, surely, can more strongly indicate design and attention to an end, than their being thus stationed, than this collocation. The nature of the muscular fibre being what it is, the purposes of the animal could be answered by no other. And not only the capacity for motion, but the aspect and symmetry of the body, is preserved by the muscles being marshalled according to this order; *e. g.*, the mouth is holden in the middle of the face, and its angles kept in a state of exact correspondency, by two muscles drawing against and balancing each other. In a hemiplegia, when the muscle on one side is weakened, the muscle on the other side draws the mouth awry.

III. Another property of the muscles, which could only be the result of care, is, their being almost universally so disposed as not to obstruct or interfere with one another's action. I know but one instance in which this impediment is perceived. We cannot easily swallow whilst we gape. This, I understand, is owing to the muscles employed in the act of deglutition being so implicated with the muscles of the lower jaw, that whilst these last are contracted, the former cannot act with freedom. The obstruction is, in this instance, attended with little inconvenience; but it shows what the effect is where it does exist; and what loss of faculty there would be if it were more frequent. Now, when we reflect upon the number of muscles, not fewer than four hundred and forty-six, in the human body, known and named,* how contiguous they lie to each other, in layers, as it were, over

* Keill's Anatomy, p. 295, ed. 3. [The number named has been considerably increased since Keill's day, so that it now amounts to no less than five hundred and twenty-seven.—AM. ED.]

one another, crossing one another, sometimes imbedded in one another, sometimes perforating one another—an arrangement which leaves to each its liberty, and its full play, must necessarily require meditation and counsel.

IV. The following is oftentimes the case, with the muscles. Their action is wanted where their situation would be inconvenient. In which case, the body of the muscle is placed in some commodious position at a distance, and made to communicate with the point of action by slender strings or wires. If the muscles which move the fingers had been placed in the palm or back of the hand, they would have swelled that part to an awkward and clumsy thickness. The beauty, the proportions of the part, would have been destroyed. They are, therefore, disposed in the arm, and even up to the elbow, and act by long tendons strapped down at the wrist, and passing under the ligaments to the fingers, and to the joints of the fingers, which they are severally to move. In like manner, the muscles which move the toes and many of the joints of the foot, how gracefully are they disposed in the calf of the leg, instead of forming an unwieldy tumefaction in the foot itself! The observation may be repeated of the muscle which draws the nictitating membrane over the eye. Its office is in the front of the eye; but its body is lodged in the back part of the globe, where it lies safe, and where it encumbers nothing.

V. The great mechanical variety in the figure of the muscles may be thus stated. It appears to be a fixed law that the contraction of a muscle shall be towards its centre. Therefore the subject for mechanism on each occasion is, so to modify the figure and adjust the position of the muscle, as to produce the motion required agreeably with this law. This can only be done by giving to different muscles a diversity of configuration, suited to their several offices, and to their situation with respect to the work which they have to perform. On which account we find them under a multiplicity of forms and attitudes; sometimes with double, sometimes with treble tendons, sometimes with none: sometimes one tendon to several

muscles, at other times one muscle to several tendons. The shape of the organ is susceptible of an incalculable

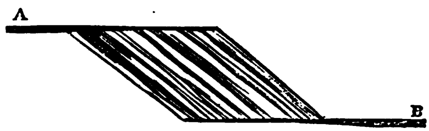
[*a*, *b*, the biceps and brachiæus internus muscles, which, by their contraction, bend the elbow; *c*, the muscle antagonist to the biceps, which straightens the arm at the elbow; *d*, *d*, the annular ligament at the wrist, which binds down the tendons that go to the fingers.—AM. ED.]

variety, whilst the original property of the muscle, the law and line of its contraction, remains the same, and is sim-

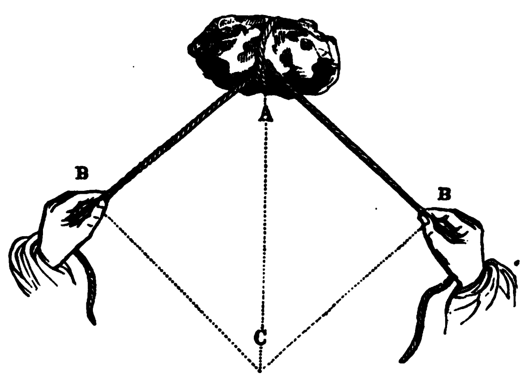
ple. Herein the muscular system may be said to bear a perfect resemblance to our works of art. An artist does not alter the native quality of his materials, or their laws of action. He takes these as he finds them. His skill and ingenuity are employed in turning them, such as they are, to his account, by giving to the parts of his machine a form and relation, in which these unalterable properties may operate to the production of the effects intended.[25]

VI. The ejaculations can never too often be repeated —How many things must go right for us to be an hour at ease! how many more for us to be vigorous and active! Yet vigor and activity are, in a vast plurality of instances, preserved in human bodies, notwithstanding that they de-

[25] In the figure of a muscle, given in page 149, it may be observed that the tendons are on different sides of the muscle.



If we were to plan their arrangement it would be thus: A is the tendinous origin, and B the tendinous insertion; and the muscular fibres run obliquely between them. This obliquity of the fibres is almost universal in the muscles of the limb, and the effect is very important. It needs no reference to mechanics to understand, that if we pull oblique-



pend upon so great a number of instruments of motion, and notwithstanding that the defect or disorder sometimes of a very small instrument, of a single pair, for instance, out of the four hundred and forty-six muscles which are employed, may be attended with grievous inconveniency. There is piety and good sense in the following observation taken out of the 'Religious Philosopher.' "With much compassion," says this writer, "as well as astonishment at the goodness of our loving Creator, have I considered the sad state of a certain gentleman, who, as to the rest, was in pretty good health, but only wanted the use of these *two little muscles* that serve to lift up the eyelids, and so had almost lost the use of his sight, being forced, as long as this defect lasted, to shove up his eyelids every moment with his own hands!" In general, we may remark in how small a degree those who enjoy the perfect use of their organs know the comprehensiveness of the blessing, the variety of their obligation. They perceive a result, but they think little of the multitude of concurrences and rectitudes which go to form it.

Besides these observations, which belong to the muscular organ as such, we may notice some advantages of structure which are more conspicuous in muscles of a certain class or description than in others. Thus:

ly upon a weight we sacrifice a great deal of power. For what advantage, then, is power resigned in the muscle? "If you wish to draw a thing towards any place with the least force, you must pull directly in the line between the thing and the place; but if you wish to draw it as quickly as possible, and do not regard the loss of force, you must pull it obliquely, by drawing it in two directions at once. Tie a string to a stone A, and draw it straight towards you at C with one hand; then make a loop on another string, and running the first through it, draw one string in each hand at B B, not towards you, in the line A C, but sideways, till both strings are stretched in a straight line: you will see how much swifter the stone moves than it did before when pulled straightforward. Now this is proved by mathematical reasoning to be the necessary consequence of forces applied obliquely; there is a loss of power, but a great increase of velocity. The velocity is the thing required to be gained."*

By the liberal employment of muscular power, quickness and variety of motion are obtained, and with the advantages which are so well described in the succeeding part of this chapter.—Eng. Ed.

* Preliminary Treatise on the Objects, Advantages, and Pleasures of Science. (*Library of Useful* Knowledge.)

I. The variety, quickness, and precision of which muscular motion is capable are seen, I think, in no part so remarkably as in the *tongue*. It is worth any man's while to watch the agility of his tongue, the wonderful promptitude with which it executes changes of position, and the perfect exactness. Each syllable of articulated sound requires for its utterance a specific action of the tongue, and of the parts adjacent to it. The disposition and configuration of the mouth appertaining to every letter and word, is not only peculiar, but, if nicely and accurately attended to, perceptible to the sight; insomuch, that curious persons have availed themselves of this circumstance to teach the deaf to speak, and to understand what is said by others. In the same person, and after his habit of speaking is formed, one, and only one, position of the parts will produce a given articulate sound correctly. How instantaneously are these positions assumed and dismissed! how numerous are the permutations, how various, yet how infallible! Arbitrary and antic variety is not the thing we admire; but variety obeying a rule, conducing to an effect, and commensurate with exigences infinitely diversified. I believe, also, that the anatomy of the tongue corresponds with these observations upon its activity. The muscles of the tongue are so numerous, and so implicated with one another, that they cannot be traced by the nicest dissection; nevertheless (which is a great perfection of the organ) neither the number, nor the complexity, nor what might seem to be the entanglement of its fibres, in anywise impede its motion, or render the determination or success of its efforts uncertain.

I here entreat the reader's permission to step a little out of my way, to consider *the parts of the mouth* in some of their other properties. It has been said, and that by an eminent physiologist, that, whenever Nature attempts to work two or more purposes by one instrument, she does both or all imperfectly. Is this true of the tongue

regarded as an instrument of speech and of taste, or regarded as an instrument of speech, of taste, and of deglutition? So much otherwise, that many persons, that is to say, nine hundred and ninety-nine persons out of a thousand, by the instrumentality of this one organ, talk, and taste, and swallow very well. In fact, the constant warmth and moisture of the tongue, the thinness of the skin, the papillæ upon its surface, qualify this organ for its office of tasting, as much as its inextricable multiplicity of fibres do for the rapid movements which are necessary to speech. Animals which feed upon grass have their tongues covered with a perforated skin, so as to admit the dissolved food to the papillæ underneath, which, in the mean time, remain defended from the rough action of the unbruised spiculæ.

There are brought together within the cavity of the mouth more distinct uses, and parts executing more distinct offices, than I think can be found lying so near to one another, or within the same compass, in any other portion of the body: viz., teeth of different shape, first for cutting, secondly for grinding; muscles, most artificially disposed for carrying on the compound motion of the lower jaw, half lateral and half vertical, by which the mill is worked; fountains of saliva, springing up in different parts of the cavity for the moistening of the food, whilst the mastication is going on; glands, to feed the fountains; a muscular constriction of a very peculiar kind in the back part of the cavity, for the guiding of the prepared aliment into its passage towards the stomach, and in many cases for carrying it along that passage; for, although we may imagine this to be done simply by the weight of the food itself, it in truth is not so, even in the upright posture of the human neck; and most evidently is not the case with quadrupeds—with a horse, for instance, in which, when pasturing, the food is thrust upward by muscular strength instead of descending of its own accord.

In the mean time, and within the same cavity, is going on another business, altogether different from what is here described—that of respiration and speech. In addition, therefore, to all that has been mentioned, we have a pas-

sage opened from this cavity to the lungs, for the admission of air exclusively of every other substance: we have muscles, some in the larynx, and without number in the tongue, for the purpose of modulating that air in its passage, with a variety, a compass, and precision, of which no other musical instrument is capable. And lastly, which, in my opinion, crowns the whole as a piece of machinery, we have a specific contrivance for dividing the pneumatic part from the mechanical, and for preventing one set of actions interfering with the other. Where various functions are united, the difficulty is, to guard against the inconveniencies of a too great complexity. In no apparatus put together by art and for the purposes of art, do I know such multifarious uses so aptly combined, as in the natural organization of the human mouth; or where the structure, compared with the uses, is so simple. The mouth, with all these intentions to serve, is a single cavity; is one machine; with its parts neither crowded nor confused, and each unembarrassed by the rest: each, at least, at liberty in a degree sufficient for the end to be attained. If we cannot eat and sing at the same moment, we can eat one moment and sing the next: the respiration proceeding freely all the while.

There is one case, however, of this double office, and that of the *earliest* necessity, which the mouth alone could not perform; and that is, carrying on together the two actions of sucking and breathing. Another route, therefore, is opened for the air—namely, through the nose—which lets the breath pass backward and forward, whilst the lips, in the act of sucking, are necessarily shut close upon the body from which the nutriment is drawn. This is a circumstance which always appeared to me worthy of notice. The nose would have been necessary, although it had not been the organ of smelling. The making it the seat of a sense was superadding a new use to a part already wanted; was taking a wise advantage of an antecedent and a constitutional necessity.[26]

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[26] When our author describes the variety of functions performed by the *mouth and tongue*, he is in admiration at the simplicity of the

[OF THE MOUTH.

Our author has said that every thing in the structure of the mouth is mechanical, and he has given a very attractive view of the varieties of the mechanism in the mouths and bills of animals. But so far from exhausting the subject, he has left some of the most interesting particulars untouched. In man, the mouth is not flat because he has hands, but because it is a part of that apparatus, which is the most curious and important of all the bodily structures, —the instrument of speech. In that light we shall presently take it up separately, not doubting that it will reward the reader's attention. Let us, in the mean time, consider some of the common properties of the mouth; and first, of the most obvious parts, the lips. Nothing serves better to make us appreciate the blessings we enjoy, than examining the organization of a part which, from its familiarity, and the absolute perfection of its action, we neglect or think meanly of. The lips receive the food, and aid in mastication; they are a principal

instrument. But this is only an apparent simplicity: the complexity of structure is concealed. Indeed, it has been this very consideration which led to the new investigations into the nervous system. Without entering far into this subject, we take the tongue in illustration. It is a fine organ of touch: it is the seat of the sense of taste: it is necessary to deglutition: its modulations are infinite in speech; but the reason of a body so simple in its outward form being capable of performing offices apparently so discordant, is visible only to the anatomist, who traces the nerves into this organ. Then he discovers, besides the nerve preceeding from the papillæ of the tongue to the sensorium, that there are nerves of volition governing the muscles of the tongue. In addition to these, there is a nerve which regulates the action of swallowing, and which combines the motions of the gullet with those of the tongue; and in the same manner another nerve, tending to the organ of voice in the larynx, branches off to the tongue, and associates it with the organ of the voice, so as to produce articulate language: these nervous cords are the true organization by which one member, simple in its exterior form, has a complexity in its internal relations. And thus it is, that in many instances organs which are apparently simple, and through which we perform many offices so easily that we think not at all of what is necessary to their execution, have yet internally, and to the eye of the anatomist, a thousand minute circumstances or relations, on which the *perfection* of their action depends.—ENG. ED.

part of the organ of speech; they are expressive of emotion; they are the most acutely sensible to touch. But all this never moves our surprise or admiration.

If we know any thing of muscularity, we must presume that there is a concourse of fine muscles converging to the lips and surrounding them. But what gives the lips their sensibility? This was a question early suggested to me in my investigations on the nerves; when experiment showed that one nerve went to the lips for sensation, and another for motion. The vermilion surfaces of the lips possess their exquisite sensibility through minute and delicate villi, into which the extremities of the sensitive nerve are distributed: and these, being covered only by a cuticle the most thin and transparent, afford the ready instrument of touch. We see how the child uses the lips, as giving him his first information of the qualities of bodies.

It is certainly an unexpected thing to find that two organizations totally distinct, combined in the lips, should be necessary to the simplest act. If the nerve of motion be cut and has lost its function, the animal puts its lips to the grains it feeds upon, but cannot gather them. If the nerve of sensation be injured, the animal presses its lips to the food, but wants the sensibility by which the motions of the lips should be directed. These facts show, that whilst sensibility and motion are distinct faculties, and depend upon different nerves, they are necessarily combined for so simple an act as taking the food into the mouth. We thus daily see that in paralysis, sometimes one property is lost, sometimes another; a circumstance most important to the physician.

As connected with our present subject, it is a strange thing to see that, whilst a person may have every capacity for motion in the lips and tongue, he will have the morsel remaining in the mouth without knowing it. The first instance I found of a defect in the lips, exactly similar to that produced by cutting the nerve of sensation on one side of the face, was in a gentleman who, being under the hands of his dentist, had the nerve of sensation hurt by the pulling of a tooth; and having a glass of water given to him, remarked that the glass was a broken one: the fact

being, that the portion of the tumbler in contact with one half of his lips was not felt at all, which gave him the same sensation as if a bit of the glass had been broken away.

We might show, in the lower creatures, an infinite variety in the forms of the mouth; but even in the mammalia, we may perceive that the lips are projected, and have a power almost like that of the hand. The horse has great power in his lips. The camel, the elk, but more especially the rhinoceros, have a still greater mobility, and the latter has a very fine sensibility in the hook-shaped extension of its upper lip: the snout of the tapir and the trunk of the elephant belong to the lips, rather than to the nostrils. We have the least equivocal proof of this, in their supply of nerves, which are only an enlargement or prolongation of those nerves which in man go to the lips. Nay, we may state a fact, perhaps unexpected to the reader, that the whiskers of animals of the cat tribe have, entering into their roots, branches of the same nerve which gives sensibility to the lips; and the palpa and tentacula in the lower classes of animals, as the crustacea and insects, however different these organs may appear, are known to belong to this order of parts, by the same proofs, their supply of nerves.

We might be tempted here to speak of the bills of birds, had they not already attracted the attention of our author. We shall, therefore, rather fortify his conclusions by attention to the structure of the tongue. The human tongue is, no doubt, the most admirable of all the organs. We might have very obvious proofs of intention and adaptation in the long rough tongue of the ox, or in the still more curious and active tongue of the camelopard, or in the tongue of the insectivorous animals, the bear, the chameleon, and anteater, or in the variety of curious instruments, darts or saws, sheathed in the bills of insectivorous birds. But we ourselves have an organ, however apparently simple, finer then all these. The human tongue, containing muscular fibres in every possible direction, and round, soft, and mobile, is less admirable as an organ of mastication, of taste, or touch, than as the organ of speech, mod ulating with every possible variety the sounds issuing from

the windpipe. On the upper surface of what is termed the dorsum of the tongue, there are rough papillæ, which in some measure correspond with what we see in animals: they are subservient to the taste. Some of them have a mushroom-like top, and a stalk projecting from the bottom of a little hollow, and there the sapid particles of the food lodge, and prolong the enjoyment of the palate. But, in the organization of the tongue, there is one minute point of structure more curious than all the rest. When the papillæ are examined with a magnifying glass, there are seen certain small bodies, consisting of a gray sheath, within which there is a little red point; and this point is capable of erection, thus projecting and becoming the organ of taste. It is so erected when the morsel is in the mouth, or when we are in the immediate anticipation of food. There are other more minute processes studding the surface of the tongue, and these contain the extremities of nerves which are sensible to touch. It must surely, therefore, be considered an admirable thing to find so many faculties seated here, each with its appropriate organization, and each most curiously connected with other structures —that we should have the power of mastication, of deglutition, of modulation of the voice, the senses of taste and of touch, concentrated in one apparently simple organ.

Not to speak of other relations, can there be any better proof of design, than the effects of the excited sensibility of the tongue? No sooner have these gustatory points of nerves been excited, than there is poured out into the mouth most abundantly, by four distinct tubes, the saliva, that fluid* which facilitates mastication, and directly prepares the food for the action of the stomach. And however well we might imagine such a supply of fluid to assist deglutition, this is not all that is here done in preparation; for whilst the morsel is moved by tongue, and lips, and jaws, an appropriate fluid is collecting in what appear to be mere irregularities in the back part of the throat, but

* We presume that the fluid is chiefly useful in mastication, as the glands are large, and the fluid most abundant in animals that chew the cud. In all, these glands are so disposed as to receive gentle pressure from the motion of the jaw; so that, whilst their vascular apparatus is excited by the sensibilities of the tongue, *the fluid is urged from the ducts* by the pressure of the jaw and muscles which *move it. The fluid itself* is neither acid nor alkaline.

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which are, in truth, so many receptacles, that pointing towards the stomach, give out their contents as the morsel passes.

There is one curious circumstance which we may notice before quitting this subject. Eating seems always to be an act of the will, and attended with gratification. It is well known that the operation, or what is very nearly the same, may go on within the stomach, without any outward sign at least of pleasure. The gizzard (with which we are most familiar in fowls, though it be, in fact, found in the vegetable-feeders of the different classes of animals) is correctly enough described as an organ of mastication, in which there is an incessant and alternate action of opponent muscles, as in the motions of the jaws. In the stomach of the lobster we have not merely the muscles of mastication, but the teeth also ; so that it appears the function may be performed altogether internally, and without the volition, and probably without the sensations, that accompany the offices of the mouth. We mention this, as drawing the reader to comprehend that many organs may be in operation in the internal economy, without our consciousness.

Our author, with much propriety, from time to time, adverts to those changes in the organization which accommodate the animal to new conditions. Now, in terrestrial animals, the act of swallowing must be accommodated to the atmosphere; but if the animal lives in water, and still breathes the air, the structure of the parts must be changed. The crocodile seizes its prey, and descends into the water with it. Its power of descending does not, as in the fish, result from compressing the air-bladder: but is owing to a provision in its ribs and lungs. Unless the crocodile could expel the air from its lungs in a greater degree than the mammalia are capable of doing, it could not crawl upon the bottom, nor retain its place there without continual exertion. There is an adaptation to this mode of destroying its prey, by carrying it under water, in the mouth, as well as in the thorax and lungs. The

crocodile has no lips; it lies on the shore basking with its mouth open, and flies light upon and crawl into its mouth. Against these the air-tubes are protected, not by the lips and sensibility of the mouth, but by an apparatus which separates the mouth from the throat and windpipe. This partition between the cavities is necessary when the animal seizes its prey; for as it plunges under the water with open mouth, the air-tube must be protected against the ingress of the water. For this purpose, there is a transverse ridge, arising from the body of the bone of the tongue, which raises a duplicature of the membrane so as to form a septum across the back part of the mouth; whilst the curtain of the soft palate, hanging from above, meets the margin of the lower septum, and they form together a complete partition between the anterior and posterior cavities. Thus the animal is enabled to hold its prey in the open mouth, without admitting the water to the air-passages.

With these observations, we hope the reader will return to peruse, with increased interest, the conclusions so well stated by our author.—SIR CHARLES BELL.]

But to return to that which is the proper subject of the present section—the celerity and precision of muscular motion. These qualities may be particularly observed in the execution of many species of instrumental *music*, in which the changes produced by the hand of the musician are exceedingly rapid; are exactly measured, even when most minute; and display, on the part of the muscles, an obedience of action alike wonderful for its quickness and its correctness.

Or, let a person only observe his own hand whilst he is *writing*; the number of muscles which are brought to bear upon the pen; how the joint and adjusted operation of several tendons is concerned in every stroke, yet that five hundred such strokes are drawn in a minute. Not a letter can be turned without more than one, or two, or three tendinous contractions, definite, both as to the choice of the tendon, and as to the space through which the contraction *moves*; yet how currently does the work pro-

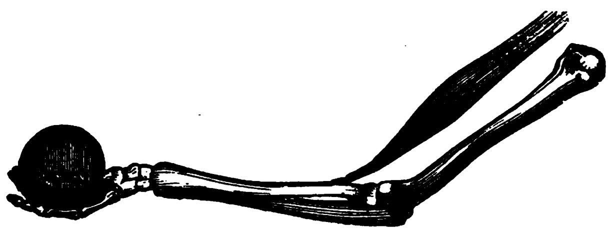
ceed! and when we look at it, how faithful have the muscles been to their duty—how true to the order which endeavor or habit hath inculcated! For let it be remembered, that, whilst a man's handwriting is the same, an exactitude of order is preserved, whether he write well or ill. These two instances of music and writing show not only the quickness and precision of muscular action, but the docility.

II. Regarding the particular configuration of muscles, *sphincter* or circular muscles appear to be admirable pieces of mechanism. It is the muscular power most happily applied; the same quality of the muscular substance, but under a new modification. The circular disposition of the fibres is strictly mechanical; but, though the most mechanical, is not the only thing in sphincters which deserves our notice. The regulated degree of contractile force with which they are endowed, sufficient for retention, yet vincible when requisite, together with their ordinary state of actual contraction, by means of which their dependence upon the will is not constant but occasional, gives to them a constitution of which the conveniency is inestimable. This their semi-voluntary character, is exactly such as suits with the wants and functions of the animal.

III. We may also, upon the subject of muscles, observe, that many of our most important actions are achieved by the combined help of different muscles. Frequently, a diagonal motion is produced by the contraction of tendons pulling in the direction of the sides of the parallelogram. This is the case, as hath been already noticed, with some of the oblique nutations of the head. Sometimes the number of cooperating muscles is very great. Dr. Nieuentyt, in the Leipsic Transactions, reckons up a hundred muscles that are employed every time we breathe; yet we take in, or let out our breath, without reflecting what a work is thereby performed; what an apparatus is laid in of instruments for the service, and how many such contribute their assistance to the effect. Breathing with ease is a blessing of every moment; yet of all others it is that which we possess with

the least consciousness. A man in an asthma is the only man who knows how to estimate it.

IV. Mr. Home has observed,* that the most important and the most delicate actions are performed in the body by the smallest muscles; and he mentions, as his examples, the muscles which have been discovered in the iris of the eye, and the drum of the ear. The tenuity of these muscles is astonishing: they are microscopic hairs: must be magnified to be visible; yet are they real effective muscles: and not only such, but the grandest and most precious of our faculties, sight and hearing, depend upon their health and action.



[The figure here represents the action of the biceps muscle, which lies on the arm, and is *inserted* upon the radius of the fore-arm, in sustaining a weight in the hand.]

V. The muscles act in the limbs with what is called a mechanical disadvantage. The muscle at the shoulder, by which the arm is raised, is fixed nearly in the same manner as the load is fixed upon a steelyard, within a few decimals, we will say, of an inch from the centre upon which the steelyard turns. In this situation, we find that a very heavy draught is no more than sufficient to countervail the force of a small lead plummet, placed upon the long arm of the steelyard, at the distance of perhaps fifteen or twenty inches from the centre, and on the other side of it. And this is the disadvantage which is meant; and an absolute disadvantage, no doubt, it would be, if the object were to spare the force of muscular contraction. But observe how conducive is this constitution to

* Phil. Trans. part i. 1800, p. 8.

animal conveniency. Mechanism has always in view one or other of these two purposes—either to move a great weight slowly, and through a small space, or to move a light weight rapidly, through a considerable sweep. For the former of these purposes, a different species of lever, and a different collocation of the muscles, might be better than the present; but for the second, the present structure is the true one. Now so it happens, that the second, and not the first, is that which the occasions of animal life principally call for. In what concerns the human body, it is of much more consequence to any man to be able to carry his hand to his head with due expedition, than it would be to have the power of raising from the ground a heavier load (of two or three more hundred weight, we will suppose) than he can lift at present.

This last is a faculty, which, on some extraordinary occasions, he may desire to possess; but the other is what he wants and uses every hour or minute. In like manner, a husbandman or a gardener will do more execution, by being able to carry his scythe, his rake, or his flail, with a sufficient despatch through a sufficient space, than if, with greater strength, his motions were proportionably more confined and slow. It is the same with a mechanic in the use of his tools. It is the same, also, with other animals in the use of their limbs. In general, the vivacity of their motions would be ill exchanged for greater force under a clumsier structure.

We have offered our observations upon the structure of muscles in general; we have also noticed certain species of muscles; but there are also *single* muscles, which bear marks of mechanical contrivance, appropriate as well as particular. Out of many instances of this kind we select the following.

I. Of muscular actions, even of those which are well understood, some of the most curious are incapable of popular explanation; at least, without the aid of plates and figures.* This is in a great measure the case with a very familiar, but, at the same time, a very complicated

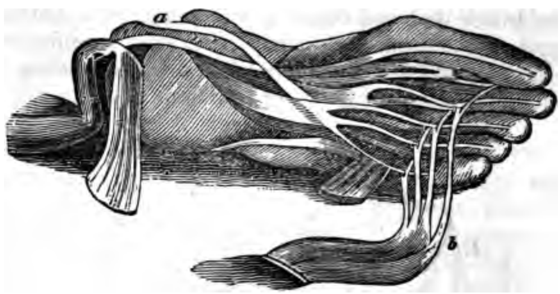
* [This edition will be found amply illustrated with all the figures necessary for a clear understanding of the text.—AM. ED.]

motion, that of the *lower jaw;* and with the muscular structure by which it is produced. One of the muscles concerned may, however, be described in such a manner as to be, I think, sufficiently comprehended for our present purpose. The problem is to pull the lower jaw *down.* The obvious method should seem to be, to place a straight muscle, viz., to fix a string from the chin to the breast, the contraction of which would open the mouth, and produce the motion required at once. But it is evident that the form and liberty of the neck forbid a muscle being laid in such a position; and that, consistently with the preservation of this form, the motion which we want must be effectuated by some muscular mechanism disposed further back in the jaw. The mechanism adopted is as follows:—A certain muscle, called the *digastric,* rises on the side of the face, considerably *above* the insertion of the lower jaw, and comes down, being converted in its progress into a round tendon. Now it is manifest that the tendon, whilst it pursues a direction *descending* towards the jaw, must, by its contraction, pull the jaw up

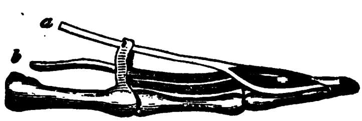
[A, the digestive muscle, which, coming down from behind the ear, perforates the muscle B, is *attached* by the ligament C, to the os hyoides D, and then, passing forwards and upwards, is inserted into the chin at E.—AM. ED.]

instead of down. What then was to be done? This, we find, is done: The descending tendon, when it is got low enough, is passed through a loop, or ring, or pulley, in the os hyoides, and then made to ascend; and having thus changed its line of direction, is inserted into the inner part of the chin: by which device, viz., the turn at the loop, the action of the muscle (which in all muscles is contraction) that before would have pulled the jaw up, now as necessarily draws it down. "The mouth," says Heister, "is opened by means of this trochlea in a most wonderful and elegant manner."

II. What contrivance can be more mechanical than the following, viz., a slit in one tendon to let another tendon pass through it? This structure is found in the tendons which move the toes and fingers. The long



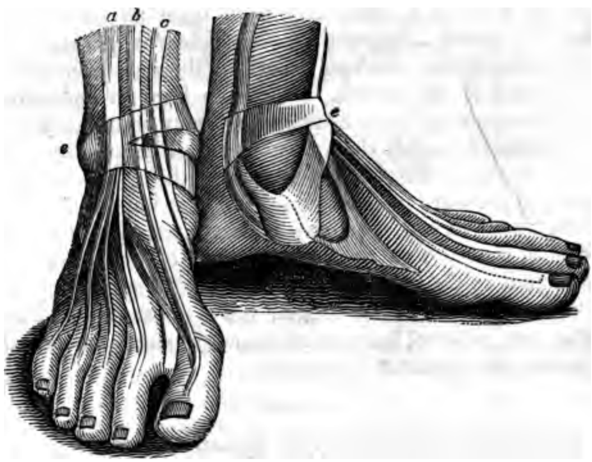
[This figure shows the long flexor tendons of the toes, *a*, passing through the small slits or openings in the short tendons, *b*.—AM. ED.]



[This cut shows the same contrivance as it exists in each of the fingers. *a*, is a tendon, which has a slit, through which passes another tendon, *b*, to be inserted near the extremity of the finger bone.—AM. ED.]

tendon, as it is called, in the foot, which bends the first joint of the toe, passes *through* the short tendon which bends the second joint, which course allows to the sinew more liberty, and a more commodious action than it would otherwise have been capable of exerting.* There is nothing, I believe, in a silk or cotton mill, in the belts, or straps, or ropes, by which motion is communicated from one part of the machine to another, that is more artificial, or more evidently so, than this *perforation*.

III. The next circumstance which I shall mention, under this head of muscular arrangement, is so decisive a mark of intention, that it always appeared to me to supersede, in some measure, the necessity of seeking for any other observation upon the subject; and that circumstance is, the tendons which pass from the leg to the foot, being



[This figure represents the band, round the ancle, to bind down the tendons going to the toes. *a*, *b*, tendons of the extensor muscles of the toes; *c*, a tendon of the flexor of the foot; *e*, the annular ligament of the instep, or band round the ancle confining the tendons *a*, *b*, *c*.—AM. ED.]

* Ches. Anat. p. 119.

bound down by a ligament to the ancle. The foot is placed at a considerable angle with the leg. It is manifest, therefore, that flexible strings, passing along the interior of the angle, if left to themselves, would, when stretched, start from it. The obvious preventive is to tie them down. And this is done in fact. Across the instep, or rather just above it, the anatomist finds a strong ligament, *under* which the tendons pass to the foot. The effect of the ligament as a bandage can be made evident to the senses; for, if it be cut, the tendons start up. The simplicity, yet the clearness of this contrivance, its exact resemblance to established resources of art, place it amongst the most indubitable manifestations of design with which we are acquainted.

There is also a further use to be made of the present example, and that is, as it precisely contradicts the opinion that the parts of animals may have been all formed by what is called *appetency*, *i. e.*, endeavor perpetuated and imperceptibly working its effect, through an incalculable series of generations. We have here no endeavor, but the reverse of it—a constant renitency and reluctance. The endeavor is all the other way. The pressure of the ligament constrains the tendons; the tendons react upon the pressure of the ligament. It is impossible that the ligament should ever have been generated by the exercise of the tendon, or in the course of that exercise, forasmuch as the force of the tendon perpendicularly resists the fibre which confines it, and is constantly endeavoring, not to form, but to rupture and displace, the threads of which the ligament is composed.

Keill has reckoned up in the human body four hundred and forty-six muscles,* dissectible and describable; and hath assigned a use to every one of the number. This cannot be all imagination.

Bishop Wilkins hath observed, from Galen, that there are at least ten several qualifications to be attended to in each particular muscle—viz., its proper figure; its just magnitude; its fulcrum; its point of action, supposing the

* [See note, page 210.—AM. ED.]

figure to be fixed ; its collocation with respect to its two ends, the upper and the lower ; the place ; the position of the whole muscle ; the introduction into it of nerves, arteries, veins. How are things including so many adjustments, to be made ; or, when made, how are they to be put together, without intelligence ?

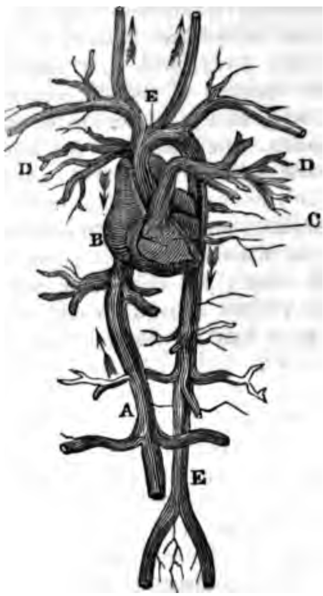
I have sometimes wondered, why we are not struck with mechanism in animal bodies, as readily and as strongly, as we are struck with it, at first sight, in a watch or a mill. One reason of the difference may be, that animal bodies are, in a great measure, made up of soft, flabby substances, such as muscles and membranes ; whereas we have been accustomed to trace mechanism in sharp lines, in the configuration of hard materials, in the moulding, chiselling, and filing into shapes, of such articles as metals or wood. There is something, therefore, of habit in the case ; but it is sufficiently evident, that there can be no proper reason for any distinction of the sort. Mechanism may be displayed in the one kind of substance, as well as in the other.

Although the few instances we have selected, even as they stand in our description, are nothing short, perhaps, of logical proofs of design, yet it must not be forgotten, that in every part of anatomy, description is a poor substitute for inspection. It is well said by an able anatomist,* and said in reference to the very part of the subject of which we have been treating, "Imperfecta hæc musculorum descriptio, non minùs arida est legentibus, quàm inspectantibus fuerit jucunda eorundem præparatio. Elegantissima enim mechanicês artificia, creberrimè in illis obvia, verbis nonnisi obscurè exprimuntur ; carnium autem ductu, tendinum colore, insertionum proportione, et trochlearium distributione, oculis exposita, omnem superant admirationem."

* Steno, in Blas. Anat. Animal. p. 2. c, 4. [This imperfect description of the muscles is no less dry to the reader, than the arrangement of them would be agreeable to the observer. For the very beautiful mechanical contrivances continually apparent in them can be but obscurely described in language. Indeed, in the conformation of their fleshy parts, in the color of the tendons, in the symmetry of the insertions, and the distribution of the pulleys, laid open to the sight, they *surpass all admiration.*—AM. ED.]

CHAPTER X.

OF THE VESSELS OF ANIMAL BODIES.



[The figure represents the heart and great blood-vessels, and may convey some idea of the circulation of the blood. We understand A to be the great vein returning the blood from the body ; B, the right sinus or auricle. From this cavity of the heart, the blood is carried into C, the ventricle ; and from this ventricle the pulmonary artery goes off. This great artery of the lungs is for the conveyance of the blood which is returned from the body into the lungs. Now the great vein, A, the auricle, B, the ventricle, C, and the pulmonary artery, DD, belong to the right side of the heart; or, to take a more important distinction, they convey dark-colored blood, which is unfit for the uses of the system.

But when this blood reaches the lungs, and is exposed to the atmosphere we breathe, it throws off the carbon, becomes bright in color, and is called arterial blood. It returns to the heart, not to the cavities which we have enumerated, but by the veins of the lungs to the other side of the heart, the left—that is, to another auricle and another ventricle. From this left ventricle there ascends the aorta, the great artery of the body, E E. This great vessel conveys the blood to every part that has life. From all the parts of the body, the blood is gathered again by the extremities of the veins, and so returns to the point of the auricle from which we began to trace it. This short preface may make the observations of the author easily intelligible.]

THE circulation of the *blood* through the bodies of men and quadrupeds, and the apparatus by which it is carried on, compose a system, and testify a contrivance, perhaps the best understood of any part of the animal frame. The lymphatic system, or the nervous system, may be more subtile and intricate; nay, it is possible that, in their structure, they may be even more artificial than the sanguiferous: but we do not know so much about them.

The utility of the circulation of the blood I assume as an acknowledged point. One grand purpose is plainly answered by it—the distributing to every part, every extremity, every nook and corner of the body, the nourishment which is received into it by one aperture. What enters at the mouth, finds its way to the fingers' ends. A more difficult mechanical problem could hardly, I think, be proposed, than to discover a method of constantly repairing the waste, and of supplying an accession of substance to every part of a complicated machine at the same time.

This system presents itself under two views: first, the disposition of the blood-vessels, *i. e.*, the laying of the pipes; and, secondly, the construction of the engine at the centre, viz., the heart, for driving the blood through them.

I. *The disposition* of the blood-vessels, as far as re-

gards the supply of the body, is like that of the water-pipes in a city, viz., large and main trunks branching off by smaller pipes (and these again by still narrower tubes) in every direction and towards every part in which the fluid which they convey can be wanted. So far, the water-pipes which serve a town may represent the vessels which carry the blood from the heart. But there is another thing necessary to the blood, which is not wanted for the water; and that is, the carrying of it back again to its source. For this office, a reversed system of vessels is prepared, which, uniting at their extremities with the extremities of the first system, collects the divided and subdivided streamlets, first, by capillary ramifications into larger branches, secondly, by these branches into trunks; and thus returns the blood (almost exactly inverting the order in which it went out) to the fountain whence its motion proceeded. All which is evident mechanism.

The body, therefore, contains two systems of blood-vessels—arteries and veins. Between the constitution of the systems, there are also two differences, suited to the functions which the systems have to execute. The blood, in going out, passing always from wider into narrower tubes; and, in coming back, from narrower into wider, it is evident that the impulse and pressure upon the sides of the blood-vessel will be much greater in one case than the other. Accordingly, the arteries, which carry out the blood, are formed of much tougher and stronger coats than the veins, which bring it back. That is one difference: the other is still more artificial, or, if I may so speak, indicates still more clearly the care and anxiety of the artificer. Forasmuch as, in the arteries, by reason of the greater force with which the blood is urged along them, a wound or rupture would be more dangerous than in the veins, these vessels are defended from injury, not only by their texture, but by their situation, and by every advantage of situation which can be given them. They are buried in sinuses, or they creep along grooves made for them in the bones; for instance, the under edge of the ribs is sloped and furrowed solely for the passage of these *vessels*. Sometimes they proceed in channels, protected

by stout parapets on each side, which last description is remarkable in the bones of the fingers, these being hollowed out, on the under side, like a scoop, and with such a concavity, that the finger may be cut across to the bone, without hurting the artery which runs along it. At other times, the arteries pass in canals wrought in the substance, and in the very middle of the substance, of the bone. This takes place in the lower jaw ; and is found where there would, otherwise, be danger of compression by sudden curvature. All this care is wonderful, yet not more than what the importance of the case required. To those who venture their lives in a ship, it has been often said, that there is only an inch-board between them and death ; but in the body itself, especially in the arterial system, there is, in many parts, only a membrane, a skin, a thread. For which reason, this system lies deep under the integuments ; whereas the veins, in which the mischief that ensues from injuring the coats is much less, lie in general above the arteries ; come nearer to the surface ; are more exposed.

It may be further observed, concerning the two systems taken together, that, though the arterial, with its trunk and branches and small twigs, may be imagined to issue or proceed—in other words, to *grow* from the heart, like a plant from its root, or the fibres of a leaf from its footstalk, (which, however, were it so, would be only to resolve one mechanism into another ;) yet the venal, the returning system, can never be formed in this manner. The arteries might go on shooting out from their extremities—*i. e.*, lengthening and subdividing indefinitely ; but an inverted system, continually uniting its streams, instead of dividing, and thus carrying back what the other system carried out, could not be referred to the same process.

II. The next thing to be considered is the engine which works this machinery—viz., the ***heart***. For our purpose, it is unnecessary to ascertain the principle upon which the heart acts. Whether it be irritation excited by the contact of the blood, by the influx of the nervous fluid, or whatever else be the cause of its motion, it is something which is capable of producing, in a living muscular fibre,

reciprocal contraction and relaxation. This is the power we have to work with; and the inquiry is, how this power is applied in the instance before us. There is provided, in the central part of the body, a hollow muscle, invested with spiral fibres, running in both directions, the layers intersecting one another; in some animals, however, appearing to be semicircular rather than spiral. By the contraction of these fibres, the sides of the muscular cavities are necessarily squeezed together, so as to force out from them any fluid which they may at that time contain: by the relaxation of the same fibres, the cavities are in their turn dilated, and, of course, prepared to admit every fluid which may be poured into them. Into these cavities, are inserted the great trunks, both of the arteries which carry out the blood, and of the veins which bring it back. This is a general account of the apparatus; and the simplest idea of its action is, that by each contraction a portion of blood is forced by a syringe into the arteries; and, at each dilatation, an equal portion is received from the veins. This produces, at each pulse, a motion, and change in the mass of blood, to the amount of what the cavity contains, which, in a full-grown human heart, I understand is about an ounce, or two table-spoonfuls. How quickly these changes succeed one another, and by this succession how sufficient they are to support a stream or circulation throughout the system, may be understood by the following computation, abridged from Keill's Anatomy, p. 117, ed. 3. "Each ventricle will at least contain one ounce of blood. The heart contracts four thousand times in one hour: from which it follows, that there pass through the heart, every hour, four thousand ounces, or three hundred and fifty pounds of blood. Now the whole mass of blood is said to be about twenty-five pounds: so that a quantity of blood, equal to the whole mass of blood, passes through the heart fourteen times in one hour, which is about once in every four minutes."

Consider what an affair this is, when we come to very large animals. The aorta of a whale is larger in the bore than the main pipe of the water-works at London Bridge; and the water roaring in its passage through that pipe is

inferior, in impetus and velocity, to the blood gushing from the whale's heart. Hear Dr. Hunter's account of the dissection of a whale : "The aorta measured a foot in diameter. Ten or fifteen gallons of blood are thrown out of the heart at a stroke with an immense velocity, through a tube of a foot in diameter. The whole idea fills the mind with wonder."*

The account which we have here stated, of the injection of blood into the arteries by the contraction, and of the corresponding reception of it from the veins by the dilatation, of the cavities of the heart, and of the circulation being thereby maintained through the blood-vessels of the body, is true, but imperfect. The heart performs this office, but it is in conjunction with another of equal curiosity and importance. It was necessary that the blood should be successively brought into contact, or contiguity, or proximity with the *air*. I do not know that the chemical reason, upon which this necessity is founded, has been yet sufficiently explored. It seems to be made appear, that the atmosphere which we breathe is a mixture of two kinds of air : one, pure and vital; the other, for the purposes of life, effete, foul, and noxious ;[27] that when we have drawn in our breath, the blood in the lungs imbibes from the air thus brought into contiguity with it a portion of its pure ingredient, and at the same time gives out the effete or corrupt air which it contained, and which is carried away, along with the halitus, every time we expire. At least, by comparing the air which is breathed from the lungs, with the air which enters the lungs, it is found to have lost some of its pure part, and to have brought away with it an addition of its impure part. Whether these experiments satisfy the question as to the need which the blood stands in of being visited by continual accesses of air, is not for us to inquire into, nor material to our argument : it is sufficient to know, that in the constitution of most animals, such a necessity exists,

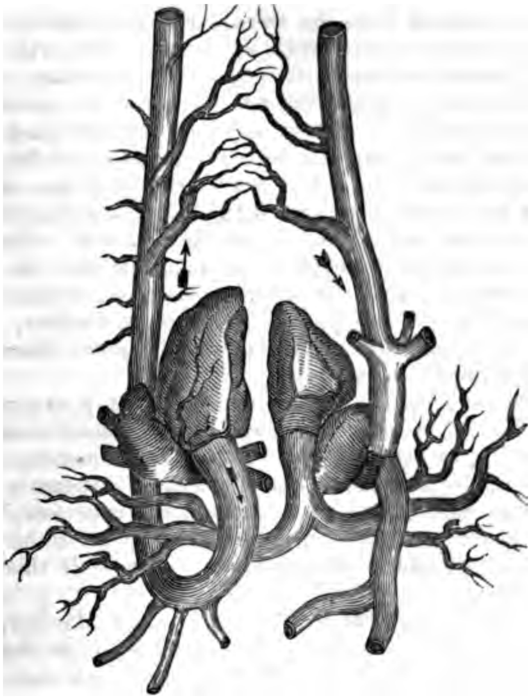
[27] The atmosphere contains, in every 100 parts, of oxygen 21 parts; nitrogen or azote, 79 parts ; carbonic acid gas, a fractional part.—Eng. Ed.

* *Dr. Hunter's Account* of the Dissection of a Whale.—(Phil. Trans.)

and that the air, by some means or other, *must* be introduced into a near communication with the blood.[28] The lungs of animals are constructed for this purpose. They consist of blood-vessels and air-vessels, lying close to each other; and whenever there is a branch of the trachea or windpipe, there is a branch accompanying it of the vein and artery, and the air-vessel is always in the middle between the blood vessels. * The internal surface of these vessels, upon which the application of the air to the blood depends, would, if collected and expanded, be, in a man, equal to a superficies of fifteen feet square. Now, in order to give the blood in its course the benefit of this organization, (and this is the part of the subject with which we are chiefly concerned,) the following operation takes place. As soon as the blood is received by the heart from the veins of the body, and *before* that is sent out again into its arteries, it is carried, by the force of the contraction of the heart, and by means of a separate and supplementary artery, to the lungs, and made to enter the vessels of the lungs; from which, after it has undergone the action, whatever it be, of that viscus, it is brought back, by a large vein, once more to the heart, in order, when thus concocted and prepared, to be thence distributed anew into the system. This assigns to the heart a double office. The pulmonary circulation is a system within a system; and one action of the heart is the origin of both.

[28] The most simple view, and the best supported, is this—that the dark venous blood, which is returning from the circulation through the body, is loaded with carbon. When it is carried to the right side of the heart, and from that into the lungs, the branches of the pulmonary artery are distributed in great minuteness on cells infinite in number. These cells communicate with the extreme branches of the windpipe; and as the atmosphere is received into these cells, the circulating blood comes to be exposed to its influence; for neither the coats of the minute vessels which contain the blood, nor the fine membrane of the cells which contain the air, prevents the influence of the atmosphere upon the blood. The carbon of the blood meeting the oxygen in the atmosphere, forms carbonic acid gas; and the air, expelled in expiration, thus loaded, carries away, of course, a portion of moisture by exhalation.—ENG. ED.

* Keill's Anatomy, p. 121.



[The figure represents the two sides of the heart separated: that to the left of the figure, but on the right side of the body, containing the venous blood which must pass through the lungs to serve the purposes of the economy; and that on the left side, containing arterial blood, which is sent out into the body. Man, and all animals of warm blood, have the whole mass of blood passing through the lungs, and a double heart, as here represented, each consisting of a vein, an auricle, a ventricle, and an artery. The arrows point out the course of the circulation.]

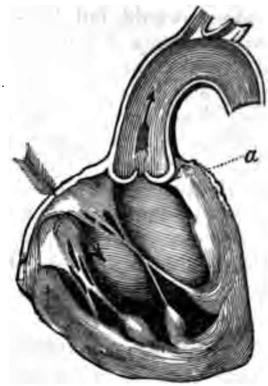
For this complicated function, four cavities become necessary, and four are accordingly provided: two called ventricles, which *send out* the blood, viz., one into the lungs, in the first instance; the other into the mass, after

it has returned from the lungs; two others also, called auricles, which *receive* the blood from the veins, viz., one, as it comes immediately from the body; the other, as the same blood comes a second time after its circulation through the lungs. So that there are two receiving cavities, and two forcing cavities. The structure of the heart has reference to the lungs; for without the lungs, one of each would have been sufficient. The translation of the blood in the heart itself is after this manner: The receiving cavities respectively communicate with the forcing cavities, and, by their contraction, unload the received blood into them. The forcing cavities, when it is their turn to contract, compel the same blood into the mouths of the arteries.

The account here given will not convey to a reader ignorant of anatomy any thing like an accurate notion of the form, action, or use of the parts, (nor can any short and popular account do this;) but it is abundantly sufficient to testify contrivance; and although imperfect, being true as far as it goes, may be relied upon for the only purpose for which we offer it—the purpose of this conclusion.

"The wisdom of the Creator," saith Hamburgher, "is in nothing seen more gloriously than in the heart." And how well doth it execute its office! An anatomist, who understood the structure of the heart, might say beforehand that it would play; but he would expect, I think, from the complexity of its mechanism, and the delicacy of many of its parts, that it should always be liable to derangement, or that it would soon work itself out. Yet shall this wonderful machine go, night and day, for eighty years together, at the rate of a hundred thousand strokes every twenty-four hours, having, at every stroke, a great resistance to overcome; and shall continue this action for this length of time, without disorder and without weariness!

But further: from the account which has been given of the mechanism of the heart, it is evident that it must require the interposition of *valves;* that the success indeed of its action must depend upon these; for when any



[This figure will assist the explanation of the following pages. It presents a section of the ventricle and the artery. Suppose that the blood enters in the direction of the arrow, it passes between two valves, of very particular construction. They are of a triangular shape, and held out by little cords, which are called the *cordæ tendineæ*. These cords are attached to muscles, which, from their appearance, are called *columnæ carneæ* ; and these fibres are continuous with the fibrous substance of the heart itself. Now when the ventricle is distended with blood, the valves are drawn by their tendons in such a manner as almost to close the orifice ; and certainly so to dispose them, that the instant the blood takes a direction backward into the vein by the contraction of the ventricle, they fall together, and like a floodgate stop the current in that direction. Were there no *cordæ tendineæ* or *columnæ carneæ*, these valves would be floated back into the auricle, and lose their office. But the most admirable part of the contrivance is, that the *columnæ carneæ*, receiving the same impulse to contract as the walls of the heart itself, act at the same instant with it ; and by contracting in proportion as the walls approach each other, they hold the margins of the valves, like the leashes of a sail when bagged by the wind. The blood, being prevented passing backward, is urged into the great artery, still in the direction of the arrow. And now it will be observed, that the artery must be dilated when the heart contracts. And the artery itself being both elastic and muscular, reacting upon this impulse, it will contract while the ventricle

is dilating. The blood would fall back from the great artery into the ventricle, were it not again prevented by the mechanical intervention of valves. *a* represents the semilunar valve of the aorta at the root of that great artery; and it is a surprising thing to see how offices so nearly alike are performed by a mechanism entirely different. This valve consists of three little bags, which are driven up by the force of the blood in the natural course of the circulation; but when, by the action of the aorta, the blood makes a motion backwards, it fills these three little bags, and they fall together, and prevent the blood flowing back into the heart.]

one of its cavities contracts, the necessary tendency of the force will be to drive the enclosed blood, not only into the mouth of the artery where it ought to go, but also back again into the mouth of the vein from which it flowed. In like manner, when, by the relaxation of the fibres, the same cavity is dilated, the blood would not only run into it from the vein, which was the course intended, but back from the artery, through which it ought to be moving forward. The way of preventing a reflux of the fluid, in both these cases, is to fix valves, which, like floodgates, may open a way to the stream in one direction, and shut up the passage against it in another. The heart, constituted as it is, can no more work without valves than a pump can. When the piston descends in a pump, if it were not for the stoppage by the valve beneath, the motion would only thrust down the water which it had before drawn up. A similar consequence would frustrate the action of the heart. Valves, therefore, properly disposed, *i. e.*, properly with respect to the course of the blood which it is necessary to promote, are essential to the contrivance. *And valves so disposed are accordingly provided.* A valve is placed in the communication between each auricle and its ventricle, lest, when the ventricle contracts, part of the blood should get back again into the auricle, instead of the whole entering, as it ought to do, the mouth of the artery. A valve is also fixed at the mouth of each of the great arteries which take the blood from the heart; leaving the passage free,

so long as the blood holds its proper course forward; closing it, whenever the blood, in consequence of the relaxation of the ventricle, would attempt to flow back. There is some variety in the construction of these valves, though all the valves of the body act nearly upon the same principle, and are destined to the same use. In general, they consist of a thin membrane, lying close to the side of the vessel, and consequently allowing an open passage while the stream runs one way, but thrust out from the side by the fluid getting behind it, and opposing the passage of the blood, when it would flow the other way. Where more than one membrane is employed, the different membranes only compose one valve. Their joint action fulfils the office of a valve: for instance, over the entrance of the right auricle of the heart into the right ventricle, three of these skins or membranes are fixed, of a triangular figure, the bases of the triangles fastened to the flesh; the sides and summits loose; but, though loose, connected by threads of a determinate length, with certain small fleshy prominences adjoining. The effect of this construction is, that, when the ventricle contracts, the blood, endeavoring to escape in all directions, and amongst other directions pressing upwards, gets *between* these membranes and the sides of the passage; and thereby forces them up into such a position, as that together they constitute, when raised, a hollow cone, (the strings before spoken of hindering them from proceeding or separating further;) which cone, entirely occupying the passage, prevents the return of the blood into the auricle. A shorter account of the matter may be this: so long as the blood proceeds in its proper course, the membranes which compose the valve are pressed close to the side of the vessel, and occasion no impediment to the circulation: when the blood would regurgitate, they are raised from the side of the vessel, and, meeting in the middle of its cavity, shut up the channel. Can any one doubt of contrivance here; or is it possible to shut our eyes against the proof of it?[29]

[29] We cannot resist following up these observations with some minute notices of the appropriate structure. A sail distended with the wind

This valve, also, is not more curious in its structure, than it is important in its office. Upon the play of the valve, even upon the proportional length of the strings or

would be torn up, were not the margins secured : accordingly, the canvass is folded over a strong cord, which is called the bolt-rope. So the margins of these semilunar valves are as finely finished as any sheet from the dock-yard. There is a ligament which runs along the margin, and strengthens it to sustain the impulse of the back-stroke of the artery. And were those *cordæ tendineæ*, which we have described as like the leashes of a sail, attached to the corner of the mitral valve without further security, they would be torn off on the first pulsation. But as the leashes are secured to the bolt-ropes of the sail, so are the *cordæ tendineæ* continued into firm ligamentous cords which strengthen the valves.

Our author says well, that the valve is thrown down on the side of the artery when the blood is in its course. But were this really the case, the refluent blood would not easily catch the edge of the valve to throw it up. Now this difficulty is met very curiously, and in two different modes. The *cordæ tendineæ* prevent the margins of the mitral valve within the ventricle from flapping close against the side of the cavity ; and as to the semilunar valves, at the root of the great artery, they are prevented falling against the walls in another mode: the section of the artery at its root is not a regular circle ; but it is formed into three little bags or sinuses, and as each of the three valves has a little sinus behind it, its margin never reaches the wall of the artery. The consequence of which is, that in the instant that the column of blood takes a retrograde direction, the margins of the valve are caught, and they are thrown up to close the passage. Nothing can be more admirably mechanical.

Since our author has so properly insisted upon the mechanism of the heart as the very strength of his argument, we shall mention one circumstance, more, as showing what may be called the perfection of the workmanship. It has been explained that the valves of the great artery consist of three semicircular membranes. Now if we consider the effect of these three semicircles meeting, there must be a triangular space in their centre, an imperfection in the point of their union as it were. To remedy this defect, on the centre of the margin of each

fibres which check the ascent of the membranes, depends, as it should seem, nothing less than the life itself of the animal. We may here likewise repeat, what we before observed concerning some of the ligaments of the body, that they could not be formed by any action of the parts themselves. There are cases in which, although good uses appear to arise from the shape or configuration of a part, yet that shape or configuration itself may seem to be produced by the action of the part, or by the action or pressure of adjoining parts. Thus the bend and the internal smooth concavity of the ribs may be attributed to the equal pressure of the soft bowels; the particular shape of some bones and joints, to the traction of the annexed muscles, or to the position of contiguous muscles. But valves could not be so formed. Action and pressure are all against them. The blood, in its proper course, has no tendency to produce such things; and in its improper or reflected current has a tendency to prevent their production. Whilst we see, therefore, the use and necessity of this machinery, we can look to no other account of its origin or formation than the intending mind of a Creator. Nor can we without admiration reflect, that such thin membranes, such weak and tender instruments, as these valves are, should be able to hold out for seventy or eighty years.

Here also we cannot consider but with gratitude, how happy it is that our vital motions are *involuntary*. We should have enough to do, if we had to keep our hearts beating and our stomachs at work. Did these things depend, we will not say upon our effort, but upon our bidding, our care, or our attention, they would leave us leisure for nothing else. We must have been continually upon the watch, and continually in ear; nor would this constitution have allowed of sleep.

It might perhaps be expected, that an organ so precious,

valve, there is a little body like a small excrescence or tongue: and when these three bodies meet, they exactly fill up the triangular space which is left in the centre of the three semicircles. It is as if an ingenious workman had contrived a thing the most apposite to remedy a defect.—Eng. Ed.

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of such central and primary importance as the heart is, should be defended by *a case*. The fact is, that a membranous purse or bag, made of strong, tough materials, is provided for it; holding the heart within its cavity; sitting loosely and easily about it; guarding its substance, without confining its motion; and containing likewise a spoonful or two of water, just sufficient to keep the surface of the heart in a state of suppleness and moisture. How should such a loose covering be generated by the action of the heart? Does not the enclosing of it in a sack, answering no other purpose but that enclosure, show the care that has been taken of its preservation?

One use of the circulation of the blood, probably, (amongst other uses,) is, to distribute nourishment to the different parts of the body. How minute and multiplied the ramifications of the blood-vessels for that purpose are, and how thickly spread over at least the superficies of the body, is proved by the single observation, that we cannot prick the point of a pin into the flesh without drawing blood, *i. e.*, without finding a blood-vessel. Nor internally is their diffusion less universal. Blood-vessels run along the surface of membranes, pervade the substance of muscles, penetrate the bones. Even into every tooth, we trace, through a small hole in the root, an artery to feed the bone, as well as a vein to bring back the spare blood from it; both which, with the addition of an accompanying nerve, form a thread only a little thicker than a horse-hair.

Wherefore, when the nourishment taken in at the mouth has once reached and mixed itself with the blood, every part of the body is in the way of being supplied with it. And this introduces another grand topic, namely, the manner in which the aliment gets into the *blood*; which is a subject distinct from the preceding, and brings us to the consideration of another entire system of vessels.

III. For this necessary part of the animal economy, an apparatus is provided in a great measure capable of being what anatomists call demonstrated, that is, shown in the dead body; and a line or course of conveyance, which we can pursue by our examinations.

First, the food descends by a wide passage into the intestines, undergoing two great preparations on its way: one in the mouth by mastication and moisture—(can it be doubted with what design the teeth were placed in the road to the stomach, or that there was choice in fixing them in this situation?)—the other by digestion in the stomach itself. Of this last surprising dissolution, I say nothing: because it is chemistry, and I am endeavoring to display mechanism. The figure and position of the stomach (I speak all along with a reference to the human organ) are calculated for detaining the food long enough for the action of its digestive juice. It has the shape of the pouch of a bagpipe; lies across the body; and the pylorus, or passage by which the food leaves it, is somewhat higher in the body than the cardia, or orifice by which it enters; so that it is by the contraction of the muscular coat of the stomach that the contents, after having undergone the application of the gastric menstruum, are gradually pressed out. In dogs and cats, this action of the coats of the stomach has been displayed to the eye. It is a slow and gentle undulation, propagated from one orifice of the stomach to the other. For the same reason that I omitted, for the present, offering any observation upon the digestive fluid, I shall say nothing concerning the bile or the pancreatic juice, further than to observe upon the mechanism, viz., that from the glands, in which these secretions are elaborated, pipes are laid into the first of the intestines, through which pipes the product of each gland flows into that bowel, and is there mixed with the aliment as soon almost as it passes the stomach; adding also as a remark, how grievously this same bile offends the stomach itself, yet cherishes the vessel that lies next to it.

Secondly. We have now the aliment in the intestines converted into pulp; and, though lately consisting of ten different viands, reduced to nearly a uniform substance, and to a state fitted for yielding its essence, which is called chyle, but which is milk, or more nearly resembling milk than any other liquor with which it can be compared. For the straining off this fluid from the digested aliment in the course of its long progress through the body, my-

riads of capillary tubes, *i. e.*, pipes as small as hairs, open their orifices into the cavity of every part of the intestines. These tubes, which are so fine and slender as not to be visible unless when distended with chyle, soon unite into larger branches. The pipes formed by this union terminate in glands, from which other pipes, of a still larger diameter, arising, carry the chyle from all parts into a common reservoir or *receptacle*. This receptacle is a bag, of size enough to hold about two table-spoonfuls; and from this vessel, a duct or main pipe proceeds, climbing up the back part of the chest, and afterward creeping along the gullet till it reach the neck. Here it meets the river; here it discharges itself into a large vein, which soon conveys the chyle, now flowing along with the old blood, to the heart. This whole route can be exhibited to the eye; nothing is left to be supplied by imagination or conjecture. Now, besides the subserviency of this structure, collectively considered, to a manifest and necessary purpose, we may remark two or three separate particulars in it, which show, not only the contrivance, but the perfection of it. We may remark, first, the length of the intestines, which, in the human subject, is six times that of the body. Simply for a passage, these voluminous bowels, this prolixity of gut, seems in nowise necessary; but in order to allow time and space for the successive extraction of the chyle from the digestive aliment, namely, that the chyle which escapes the lacteals of one part of the guts may be taken up by those of some other part, the length of the canal is of evident use and conduciveness. Secondly, we must also remark their peristaltic motion, which is made up of contractions following one another like waves upon the surface of a fluid, and not unlike what we observe in the body of an earthworm crawling along the ground, and which is effected by the joint action of longitudinal and of spiral, or rather perhaps of a great number of separate semicircular fibres. This curious action pushes forward the grosser part of the aliment, at the same time that the more subtile parts, which we call chyle, are, by a series of gentle compressions, *squeezed* into the narrow orifices of the lacteal veins.

Thirdly, it was necessary that these tubes, which we denominate lacteals, or their mouths at least, should be made as narrow as possible, in order to deny admission into the blood to any particle which is of size enough to make a lodgement afterward in the small arteries, and thereby to obstruct the circulation; and it was also necessary that this extreme tenuity should be compensated by multitude; for a large quantity of chyle (in ordinary constitutions not less, it has been computed, than two or three quarts in a day) is, by some means or other, to be passed through them. Accordingly, we find the number of the lacteals exceeding all powers of computation, and their pipes so fine and slender as not to be visible, unless filled, to the naked eye, and their orifices, which open into the intestines, so small as not to be discernible even by the best microscope. Fourthly, the main pipe, which carries the chyle from the reservoir to the blood, viz., the thoracic duct, being fixed in an almost upright position, and wanting that advantage of propulsion which the arteries possess, is furnished with a succession of valves to check the ascending fluid, when once it has passed them, from falling back. These valves look upwards, so as to leave the ascent free, but to prevent the return of the chyle, if, for want of sufficient force to push it on, its weight should at any time cause it to descend. Fifthly, the chyle enters the blood in an odd place, but perhaps the most commodious place possible, viz., at a large vein in the neck, so situated with respect to the circulation as speedily to bring the mixture to the heart. And this seems to be a circumstance of great moment; for had the chyle entered the blood at an artery, or at a distant vein, the fluid composed of the old and the new materials must have performed a considerable part of the circulation before it received that churning in the lungs which is probably necessary for the intimate and perfect union of the old blood with the recent chyle. Who could have dreamt of a communication between the cavity of the intestines and the left great vein of the *neck*? Who could have suspected that this communication should be the medium through which all nourishment is derived to the body, or this the place

where, by a side inlet, the important junction is formed between the blood and the material which feeds it?

We postponed the consideration of ***digestion***, lest it should interrupt us in tracing the course of the food to the blood: but in treating of the alimentary system, so principal a part of the process cannot be omitted.

Of the gastric juice, the immediate agent by which that change which food undergoes in our stomachs is effected, we shall take our account from the numerous, careful, and varied experiments of the Abbé Spallanzani.

1. It is not a simple diluent, but a real solvent. A quarter of an ounce of beef had scarcely touched the stomach of a crow, when the solution began.

2. It has not the nature of saliva; it has not the nature of bile; but is distinct from both. By experiments out of the body, it appears that neither of these secretions acts upon alimentary substances in the same manner as the gastric juice acts.

3. Digestion is not *putrefaction*; for the digesting fluid resists putrefaction most pertinaciously; nay, not only checks its further progress, but restores putrid substances.

4. It is not a *fermentative* process; for the solution begins at the surface, and proceeds towards the centre, contrary to the order in which fermentation acts and spreads.

5. It is not the *digestion of heat*; for the cold maw of a cod or sturgeon will dissolve the shells of crabs or lobsters, harder than the sides of the stomach which contains them.

In a word, animal digestion carries about it the marks of being a power and a process completely *sui generis*,* distinct from every other, at least from every chemical process with which we are acquainted. And the most wonderful thing about it, is, its appropriation, its subserviency to the particular economy of each animal. The gastric juice of an owl, falcon, or kite will not touch grain; no, not even to finish the macerated and half-digested pulse which is left in the crops of the sparrows that the bird

* [Of its own kind—of a kind by itself.]

devours. In poultry, the trituration of the gizzard, and the gastric juice, conspire in the work of digestion. The gastric juice will not dissolve the grain whilst it is whole. Entire grains of barley, enclosed in tubes or spherules, are not affected by it. But if the same grain be by any means broken or ground, the gastric juice immediately lays hold of it. Here then is wanted, and here we find, a combination of mechanism and chemistry.[30] For the preparatory grinding, the gizzard lends its mill; and as all millwork should be strong, its structure is so beyond that of any other muscle belonging to the animal. The internal coat also, or lining of the gizzard, is, for the same purpose, hard and cartilaginous. But, forasmuch as this is not the sort of animal substance suited for the reception of glands, or for secretion, the gastric juice, in this family, is not supplied, as in membranous stomachs, by the stomach itself, but by the gullet, in which the feeding-glands are placed, and from which it trickles down into the stomach.

In sheep, the gastric fluid has no effect in digesting plants, *unless they have been previously masticated.* It only produces a slight maceration, nearly such as common water would produce, in a degree of heat somewhat exceeding the medium temperature of the atmosphere. But, provided that the plant has been reduced to pieces by chewing, the gastric juice then proceeds with it, first, by softening its substance; next, by destroying its natural consistency; and, lastly, by dissolving it so completely as not even to spare the toughest and most stringy parts, such as the nerves of the leaves.

So far our accurate and indefatigable Abbé. Dr. Stevens, of Edinburgh, in 1777, found by experiments tried with perforated balls, that the gastric juice of the sheep and the ox speedily dissolved vegetables, but made no impression upon beef, mutton, and other animal bodies. Mr. Hunter discovered a property of this fluid, of a most curious kind, viz., that in the stomachs of animals which

[30] One of the many modes by which seeds are carried to a distance, and Sir Joseph Banks gave us reason to believe that it served as a preparation for sowing, as seeds so carried germinated sooner.—Eng. Ed.

feed upon flesh, irresistibly as this fluid acts upon animal substances, it is only upon the *dead* substance that it operates at all. The *living* fibre suffers no injury from lying in contact with it. Worms and insects are found alive in the stomachs of such animals. The coats of the human stomach, in a healthy state, are insensible to its presence; yet in cases of sudden death, (wherein the gastric juice, not having been weakened by disease, retains its activity,) it has been known to eat a hole through the bowel which contains it.* How nice is this discrimination of action, yet how necessary!

But to return to our hydraulics.

IV. The gall-bladder is a very remarkable contrivance. It is the reservoir of a canal. It does not form the channel itself, *i. e.*, the direct communication between the liver and the intestine, which is by another passage, viz., the ductus hepaticus, continued under the name of the ductus communis; but it lies adjacent to this channel, joining it by a duct of its own, the ductus cysticus: by which structure it is enabled, as occasion may require, to add its contents to, and increase the flow of bile into the duodenum. And the position of the gall-bladder is such as to apply this structure to the best advantage. In its natural situation, it touches the exterior surface of the stomach, and consequently is compressed by the distension of that vessel: the effect of which compression is to force out from the bag, and send into the duodenum, an extraordinary quantity of bile, to meet the extraordinary demand which the repletion of the stomach by food is about to occasion.† Cheselden describes‡ the gall-bladder as seated against the duodenum, and thereby liable to have its fluid pressed out by the passage of the aliment through that cavity, which likewise will have the effect of causing it to be received into the intestine, at a right time and in a due proportion.

There may be other purposes answered by this contrivance, and it is probable that there are. The contents of the gall-bladder are not exactly of the same kind as

* Phil. Trans. vol. lxii. p. 447. † Keill's Anat. p. 64. ‡ Anat. p. 164.

what passes from the liver through the direct passage.* It is possible that the gall may be changed, and for some purposes meliorated, by keeping.

The entrance of the gall-duct into the duodenum furnishes another observation. Whenever either smaller tubes are inserted into larger tubes, or tubes into vessels and cavities, such receiving tubes, vessels, or cavities being subject to muscular constriction, we always find a contrivance to prevent *regurgitation*. In some cases, valves are used; in other cases, amongst which is that now before us, a different expedient is resorted to, which may be thus described: the gall-duct enters the duodenum obliquely; after it has pierced the first coat, it runs near two fingers' breadth *between* the coats before it opens into the cavity of the intestine.† The same contrivance is used in another part, where there is exactly the same occasion for it, viz., in the insertion of the ureters in the bladder. These enter the bladder near its neck, running obliquely for the space of an inch between its coats.‡ It is, in both cases, sufficiently evident that this structure has a necessary mechanical tendency to resist regurgitation: for whatever force acts in such a direction as to urge the fluid back into the orifices of the tubes, must, at the same time, stretch the coats of the vessels, and thereby compress that part of the tube which is included between them.

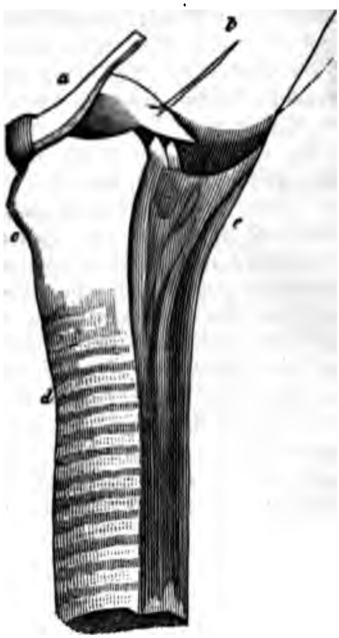
V. Amongst the *vessels* of the human body, the pipe which conveys the saliva from the place where it is made to the place where it is wanted, deserves to be reckoned amongst the most intelligible pieces of mechanism with which we are acquainted. The saliva, we all know, is used in the mouth; but much of it is produced on the outside of the cheek by the parotid gland, which lies between the ear and the angle of the lower jaw. In order to carry the secreted juice to its destination, there is laid from the gland on the outside a pipe about the thickness of a wheat straw, and about three fingers' breadth in length, which, after riding over the masseter muscle, bores

* Keill, (from Malpighius, p. 63.) † Keill's Anat. p. 62. ‡ Ches. Anat. p. 260.

for itself a hole through the very middle of the cheek, enters by that hole, which is a complete perforation of the buccinator muscle, into the mouth, and there discharges its fluid very copiously.

[A, the parotid gland, which secretes a considerable proportion of the saliva ; B, the tube or duct, through which the saliva is carried and discharged into the mouth on the inner sides of the cheeks.—AM. ED.]

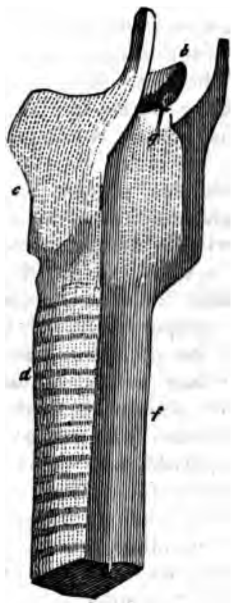
VI. Another exquisite structure, differing, indeed, from the four preceding instances, in that it does not relate to the conveyance of fluids, but still belonging, like these, to the class of pipes or conduits of the body, is seen in the *larynx*. We all know, that there go down the throat two pipes, one leading to the stomach, the other to the lungs; the one being the passage for the food, the other for the breath and voice: we know, also, that both these passages open into the bottom of the mouth—the gullet, necessarily, for the conveyance of food, and the windpipe, for speech and the modulation of sound, not much less so: therefore the difficulty was, the passages being so contiguous, to prevent the food, especially the liquids, which we swallow into the stomach, from entering the windpipe, *i. e.*, the road to the lungs; the consequence of which error, when it does happen, is perceived by the convulsive throes that are instantly produced. This business, which is very nice, is managed in this manner. The gullet (the passage for food) opens into the mouth, like the cone or upper part of a funnel, the capacity of which, forms, indeed, the bottom of the mouth. Into the side of this funnel, at the part which lies the lowest, enters the windpipe by a chink or slit, with a lid or flap, like a little tongue, accurately fitted to the orifice. The solids or liquids which we swallow, pass over this lid or flap, as they descend, by the funnel, into the gullet. Both the weight of the food, and the action of the muscles concerned in swallowing, contribute to keep the lid close down upon the aperture, whilst any thing is passing; whereas, by means of its natural cartilaginous spring, it raises itself a little, as soon as the food is passed, thereby allowing a free inlet and outlet for the respiration of air by the lungs. Such is its structure; and we may here remark the almost complete success of the expedient, viz., how seldom it fails of its purpose, compared with the number of instances in which it fulfils it. Reflect how frequently we swallow, how constantly we breathe. In a city-feast, for example, what deglutition, what anhelation! yet does this little cartilage, the epiglottis, so effectually interpose its office, so securely guard the entrance



[*a*, **the larynx,** or windpipe; ***b*, the epiglottis, pressed down, and closing the glottis, or opening of the larynx**; *c*, **the pharynx, or gullet.**—AM. ED.]

of the windpipe, that, whilst morsel after morsel, draught after draught, are coursing one another over it, an accident of a crumb or a drop slipping into this passage, (which, nevertheless, must be opened for the breath, every second of time,) excites in the whole company, not only alarm by its danger, but surprise by its novelty. Not two guests are choked in a century.

There is no room for pretending that the action of the parts may have gradually formed the epiglottis: I do not mean in the same individual, but in a succession of generations. Not only the action of the parts has no such tendency, but the animal could not live, nor consequently the parts act, either without it, or with it in a half-formed state. The species was not to wait for the gradual formation or expansion of a part, which was from the first *necessary* to the life of the individual.



[*a*, the cartilaginous rings of the larynx; *b*, the extremity of the epiglottis; *c*, the hinder, membranous part, against which, the pharynx (represented at *c*, in the preceding cut) rests.—AM. ED.]

Not only is the larynx curious, but the whole windpipe possesses a structure adapted to its peculiar office. It is made up (as any one may perceive, by putting his fingers to his throat) of stout cartilaginous ringlets, placed at small and equal distances from one another. Now this is not the case with any other of the numerous conduits of the body. The use of these cartilages is to keep the passage for the air *constantly* open, which they do mechanically. A pipe with soft membranous coats, liable to collapse and close when empty, would not have answered here; although this be the general vascular structure, and a structure which serves very well for those tubes which are kept in a state of perpetual distension by the fluid they enclose, or which afford a passage to solid and protruding substances.

Nevertheless, (which is another particularity well worthy of *notice,) these* rings are not complete, that is, are not

cartilaginous and stiff all round; but their hinder part, which is contiguous to the gullet, is membranous and soft, easily yielding to the distensions of that organ, occasioned by the descent of solid food. The same rings are also bevelled off, at the upper and lower edges, the better to close upon one another when the trachea is compressed or shortened.

The constitution of the trachea may suggest likewise another reflection. The membrane which lines its inside, is perhaps the most sensible, irritable membrane of the body. It rejects the touch of a crumb of bread, or a drop of water, with a spasm which convulses the whole frame; yet, left to itself and its proper office, the intromission of air alone, nothing can be so quiet. It does not even make itself felt; a man does not know that he has a trachea. This capacity of perceiving with such acuteness, this impatience of offence, yet perfect rest and ease when let alone, are properties, one would have thought, not likely to reside in the same subject. It is to the junction, however, of these almost inconsistent qualities, in this, as well as in some other delicate parts of the body, that we owe our safety and our comfort—our safety, to their sensibility; our comfort, to their repose.[31]

[31] Our author touches here upon the sensibilities which govern the motions of the chest—a subject which might be enlarged upon to fill a volume. But considering the object of this work, we ought not to omit the occasion of observing the union of a property of life with the most complex mechanical structure imaginable. We have seen in former notes, that for the grand and vital purpose of decarbonizing the blood, the atmospheric air must be drawn deep into the lungs; and the problem is, to permit the vital air to pass, and yet prevent foreign matter from finding access. But the more remarkable circumstance in connexion with the statement in the text is, that the whole of this apparatus for respiration, is taken from the governance of the will, and placed under a power more constantly vigilant and more absolutely peremptory. The sensibility about the glottis holds in control a hundred muscles; and whilst it excites the action, directs the force of the stream of expired air with extraordinary exactness to the very point where the irritating matter lodges, be it in the passages of the throat, or in the cavities of the nose. There are many instances of the same kind in the economy of the frame, where actions are excited by sensibilities seated in certain spots, some of them attended with suffering, by which

The larynx, or rather the whole windpipe taken together, (for the larynx is only the upper part of the windpipe,) besides its other uses, is also a musical instrument—that is to say, it is mechanism expressly adapted to the modulation of sound; for it has been found upon trial, that, by relaxing or tightening the tendinous bands at the extremity of the windpipe, and blowing in at the other end, all the cries and notes might be produced, of which the living animal was capable. It can be sounded, just as a pipe or flute is sounded.

Birds, says Bonnet, have, at the lower end of the windpipe, a conformation like the reed of a hautboy, for the modulation of their notes. A tuneful bird is a ventriloquist. The seat of the song is in the breast.

The use of the lungs *in* the system, has been said to be obscure; one use, however, is plain, though, in some sense, external to the system, and that is, the formation, in conjunction with the larynx, of voice and speech. They are, to animal utterance, what the bellows are to the organ.

For the sake of method, we have considered animal bodies under three divisions: their bones, their muscles, and their vessels; and we have stated our observations upon these parts, separately. But this is to diminish the strength of the argument. The wisdom of the Creator is seen, not in their separate but their collective action; in their mutual subserviency and dependence; in their contributing *together* to one effect and one use. It has been said, that a man cannot lift his hand to his head, without finding enough to convince him of the existence of a God. And it is well said; for he has only to reflect, familiar as this action is, and simple as it seems to be, how many things are requisite for the performing of it; how

our voluntary efforts are brought in aid, and others where there is neither sensation nor volition, and yet the muscles are controlled and regulated, and the offices performed, with undeviating precision.—ENG. ED.

many things, which we understand, to say nothing of many more, probably, which we do not: viz. first, a long, hard, strong cylinder, in order to give to the arm its firmness and tension; but which, being rigid, and, in its substance, inflexible, can only turn upon joints; secondly, therefore, joints for this purpose; one at the shoulder to raise the arm, another at the elbow to bend it; these joints continually fed with a soft mucilage to make the parts slip easily upon one another, and holden together by strong braces, to keep them in their position: then, thirdly, strings and wires—*i. e.*, muscles and tendons—artificially inserted, for the purpose of drawing the bones in the directions in which the joints allow them to move. Hitherto we seem to understand the mechanism pretty well; and, understanding this, we possess enough for our conclusion: Nevertheless, we have hitherto only a machine standing still, a dead organization, an apparatus. To put the system in a state of activity, to set it at work, a further provision is necessary—viz., a communication with the brain, by means of nerves. We know the existence of this communication, because we can see the communicating threads, and can trace them to the brain: its necessity we also know, because, if the thread be cut, if the communication be intercepted, the muscle becomes paralytic; but beyond this, we know little, the organization being too minute and subtile for our inspection.

To what has been enumerated, as officiating in the single act of a man's raising his hand to his head, must be added, likewise, all that is necessary, and all that contributes to the growth, nourishment, and sustentation of the limb, the repair of its waste, the preservation of its health: such as the circulation of the blood through every part of it; its lymphatics, exhalents, absorbents; its excretions and integuments. All these share in the result—join in the effect; and how all these, or any of them, come together without a designing, disposing intelligence, it is impossible to conceive.

[OF THE CIRCULATION.

Life, in the animal body, is attended with a never-ceasing change in the whole framework. Not merely is there a current of blood running in a circle, but all the things that enter into the composition of the animal body, solids as well as fluids, are under an influence, that keeps them in incessant change. This, indeed, is the object or end of the circulation; for the blood contains, in a fluid state, what had composed the solid framework. We might say, that the solid matter was resolved or melted, but that it is a vital action, which thus reduces the texture to the condition of a fluid. At the same time that the blood contains what has been the material of the body, it consists also of new matter, the product of digestion and assimilation, and which is destined to take the place of the material that has been removed. The circulating blood is thus made the agent, by which the revolution of the solid animal frame, as well as of the fluids, is accomplished.

We learn, by this, that there is nothing permanent in the living body. We see, and perhaps without much surprise, that a part cut, heals; that a part excavated, or taken away, is soon replaced; and, in some of the lower animals, that members cut off, are actually reproduced: all this we see, but it requires fine experiment and accurate reasoning, to enforce the conclusion, that the animal body is always growing, always forming; and that this incessant revolution in the material of the frame, is the grand distinction between the living structures of the animal body, and machinery. In the former, there is a principle of renovation incessantly at work, so that the action or exercise is attended with no wear and tear; but, on the contrary, the greater the activity, the more perfect the structure, and what we term the healing process or the reproduction of parts, is the continuance of an action, which has had no interval.

It being absolutely proved, that there is nothing permanent in the body, we leave the reader to consider the question, which forces itself upon him, "What, then, is

it, that gives identity? How comes the peculiarity of form and constitution and complexion to remain—or how does the memory serve us—when the material has been many times removed?" But we have rather to consider the grand operation by which these changes are wrought —the circulation.

Modern chemists have estimated, that 5208 grains of charcoal are thrown off from the blood, in twenty-four hours, and this, uniting with 13,392 grains of oxygen, in the atmosphere that is breathed, constitutes, with a due proportion of caloric, the carbonic acid gas, which is discharged from the lungs. Other secretions are also disposing of the material of the body; and although these be necessary to health, it is the function of respiration which is the most directly necessary to life, and which is guarded by pain and anxiety, experienced the moment that interruption is begun.

We may already comprehend, how the blood flows in a great circle, taking up the material of the body by the absorbents and veins of the body, and throwing it off by the lungs: and how blood, returning from the lungs, purified by exposure to the atmosphere, comes back to the heart to complete its circle. We readily conceive, also, how this pure blood is necessary to all the vital operations; to the nourishment and growth of the body; but it is not so easy to comprehend the manner, in which the force of the circulation ever keeps pace with the condition of the body; active, during the exercise of the body, reduced and equable, during repose; or how the body, generally, will have the circulation moderate in degree, whilst an individual part, being excited and in action, shall be accommodated with an activity of circulation, exactly apportioned to the necessity for it. It is not possible, on mere hydraulic principles, to explain how the blood shall descend to the toes, or ascend to the head, by one impulse, and yet with a force exactly proportioned to the distance and elevation of the member. Nothing is more admirable than the manner in which the heart, as the great engine in the centre, has its irritability and power of action united in close relation to the condition of the body. If

the pulse is to be felt by the physician, the person must recline; for, if he stand up, on hydraulic principles a greater force is required to move the upright column of blood, and the heart beats more rapidly; and this, especially, is more remarkable, if the person be sickly and weak. For the same reason, no physician feels the pulse when his patient is anxious or perturbed, or at least he must calculate on the pulse being accelerated. These, and many other examples, might be brought to show that the circulation alters in correspondence with the position of the body, and with its exercise; and that it alters with the emotions of the mind, as well as with the changes in the position and movement of the frame. We learn, from this, that the heart, through its sensibilities, is the regulator of the circulating system, and that it is for this purpose that it has such extensive sympathies. These remarks we premise, as reminding the reader that there are more things to be admired, in the contemplation of the living animal frame, than can be brought under the head of the mechanism of the circulating organs, or the adaptation of the tubes to the known principles of hydraulics. It is, however, to these, that we must now beg his attention.

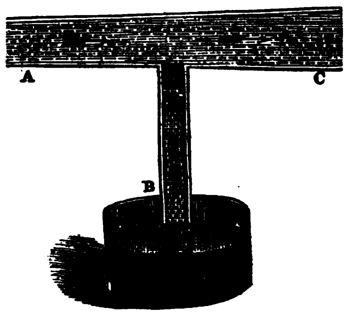
OF THE VEINS.

Our author has taken up the notion, which indeed is conveyed in anatomical books, that the veins are irregular in their form and course. We hold this to be a dangerous admission; first, because it leads to the supposition, that there is a certain imperfection, and as it were negligence, in the structure of the frame; and secondly, because it induces the inquirer to be satisfied with a very superficial survey. The veins are considered as mere conduit-pipes, to carry back the blood from all parts of the body to the heart. But they are much more; they are reservoirs. Where could that large proportion of blood which is necessary, be deposited with more safety to life than in those recesses or interstices left by the bones and muscles of the body? But whilst this object is secured, *another*, more important one, is attained, by

the turning and twisting of the veins into the crevices and unoccupied spaces: for they become thus liable to be pressed by the action of the muscles; and so it comes about, that the blood is permitted to move on slowly in these recesses, whilst we lie inactive; but when we are aroused into action, it is pressed onward, the dimensions of the reservoirs are diminished, and the blood is accumulated upon the more active heart, and is ready to answer the demands of the system which that very activity requires. The sensations at the heart exciting the respiration, the chest is expanded, and the veins enlarged; and by the alternate suction and compression upon those great veins, the heart is liberally supplied. By this arrangement, then, there is ever a correspondence preserved between the activity of the body, and the rapidity of the circulation. For this is the sequence of actions—1. We rise into activity; the blood, which was slowly circulating, is pressed forward to the heart: 2. The heart is distended and excited: 3. The sympathy or bond of union between the heart and lungs, makes a call upon the respiratory action; and the decarbonization of the blood takes place more rapidly: 4. The return of arterial blood from the lungs to the heart is accelerated, and the heart regulates the action of the arteries: 5. The increased arterial action supports the exercise of the muscular frame; and thus, there is a circle of relations established, arising out of that very seeming irregularity of the veins; their position and general condition insure an acceleration of circulation corresponding with the activity of the muscular system.

True it is, that, in comparing the branching of the veins with the arteries, there seems to be, as anatomists have taken pains to show, an appearance of clumsiness and irregularity in the former, compared with the latter; but they have not inquired, whether there was a reason for this variety—whether the distinction in the manner of a small tube joining a larger, accords with the direction of the fluid in these tubes or not—and yet this is a question, very naturally suggested, if we have a firm conviction, that in the natural body nothing is formed imperfectly, or by chance. Accordingly, it does appear, that, in the distribution of

water-pipes, it is very necessary to attend to the angle, at which a small pipe joins a larger. If a pipe be fixed into another, contrary to the direction of the stream, the discharge into that lateral branch from the larger tube will not only be much smaller than what we might estimate by the diameter of the tubes it should be, but in certain cir-



cumstances it will discharge nothing at all; nay, the water will be drawn from the lesser tube into the greater.

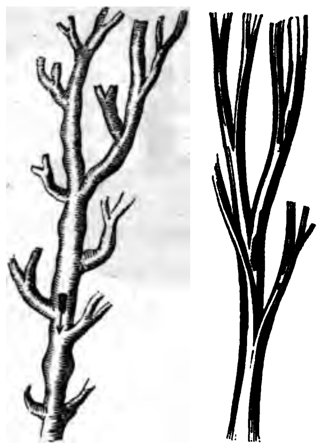
Bernouilli found, that when a small tube, B, was inserted into the side of a horizontal conical tube, A, in which the water was flowing towards the wider end, C, not only did no water escape through the smaller tube, but water in a vessel, at a considerable distance below, was drawn up through the lesser tube into the greater.

With these facts before us, we turn with interest to the curves of the arteries and veins, seeing that the contained fluids flow in the one from the trunk to the branch, in the other in an opposite direction from the smaller to the greater vessel.

And now, if, instead of taking the artery as the important vessel, and the vein as less so—and therefore negligently contrived, we consider both of them to be important and perfect—we ought to expect that their course and curves should differ.

In the artery, where the blood is passing from the heart towards the extremities—that is, from trunk to branch—the branches slightly diverge from the direction of the

stream in the trunk; whilst the branch of the vein, where the blood is passing from the lesser into the larger vessel, enters abruptly and at right angles. From this it appears, that, if we could imagine such a malformation as that the offices of these vessels were changed, congestion would immediately take place and the circulation could not be carried on.



It appears, further, that, if the veins were rigid, or placed in circumstances where their sides remained apart when wounded, instead of blood escaping, air might be drawn into them, through the expansion of the chest in breathing—and this is a most important circumstance; for, when such an accident takes place, death follows, instantaneously. When a reservoir is emptied by a perpendicular tube, into which a smaller tube is inserted, the water descending by the larger tube, instead of escaping by the lesser, will draw the water up through that lesser tube, so as to empty the glass in which its lower end is immersed. By this we see, that there may be points on the sides of tubes conveying fluid, in which the pressure may be negative; and we are made aware that the arrangement in question, instead of being a negligent or irregular joining

of the branch to the trunk, is, on the contrary, a provision

for the lesser tube entering at a proper angle into the side of the greater one.

If two tubes join to form a larger tube, and a hole be bored at the angle of their union, and if the water flow from the lesser tubes into the greater tube, no water will escape by the hole : in other words, there is a point of negative pressure. Now it is remarkable, that the vessels which are called absorbents, enter into the venous system at the angle of union of the great veins ; that is, at the point of negative pressure.

OF THE ARTERIES.

There is, perhaps, no finer proof of the adaptation of the apparatus of circulation to the principles of hydraulics, than the fact of the increasing diameters of the arteries as they recede from the heart. Mr. John Hunter took great pains to prove this : and he did demonstrate that when a great artery divided into two branches, the united areas of the branches were greater than the area of the trunk ; that when the branches subdivided, the united areas of the subdivisions were greater than the areas of the vessels from which they were derived, and so on to the extreme vessels. Reflecting on this, it is interesting to find, that the engineer, in laying down pipes, comes prac-

tically to the conclusion, that a pipe, dividing into two branches, whose united areas are exactly equal to the area of that from which they proceed, will not deliver the same quantity of water that would have flowed through the greater tube. He discovers that he must take into account the attraction and friction of the fluid upon the solid, and that the smaller the calibre of the tube, the surface of attraction or friction will be proportionably the greater. Does not this fact, coming out in practice, prove to us why the united areas of the smaller branches of the artery are larger than that of the trunk from which they are derived? If any further explanation be necessary, it is this—that the water flowing in a tube, runs more rapidly in the centre, than at the sides—or, in other words, that there is a certain attraction or friction, at the sides. We see this, in standing by a flowing river; the friction of the water, against the bottom and the sides, retards the stream, whilst the velocity of the current, is greatest in the middle. As the water in the river is delayed, at the bottom and sides, so is the fluid, nearest the sides of the tube, retarded, by the friction between the fluid and the solid. Thus we see a remarkable coincidence, between the increasing diameters of the circulating vessels, and of tubes laid down upon accurate hydraulic principles.

From the diameter of the arteries being larger as they recede from the heart, two advantages are obtained; first, that the blood is driven on with greater ease; and secondly, that the extreme arteries become, in some measure, like the veins, reservoirs of blood. A man of middling stature has thirty-three pounds of blood in his circulating vessels; and did the vessels not enlarge as they receded from the heart, there would be no place for the deposit of this great quantity of blood.

We may venture upon some further illustrations.—A stream of water, unconfined, will take a very different form, if falling by its own gravity, from what it will do, if forced in any other direction, by a *vis a tergo*.* When water is poured out of a vessel, it acquires velocity as it

* [A propelling force from behind.]

descends; the column is largest above, and drawn fine below, because it is increasing in velocity, and the stream that has a greater velocity, must be smaller in diameter: but continuing to descend, the stream acquires such a degree of velocity, that the atmosphere offers resistance, and then it again spreads out. But a column of water sent upwards, as a *jet d'eau*, [artificial fountain,] instead of contracting, as it ascends, enlarges. The fluid is retarded, as it mounts: and the stream being still propelled, from below, it is forced between the filaments of the column above, and disperses them, enlarging the column, as it ascends, and giving it a conical form. Hence it follows, that if water is to be discharged from a reservoir, along a horizontal tube, it will flow more rapidly if the tube be a cone, with its lesser end inserted into the reservoir; for the weight of the water in the reservoir still being a *vis a tergo*, and the stream from behind forcing itself between the filaments of the column, and so dispersing them, it is clear that the increasing diameter of the tube, will correspond with the natural enlargement of the column of water, and give it an unimpeded exit. Here, then, we have another explanation of the increasing diameter of the arteries, to receive the blood propelled by the heart.

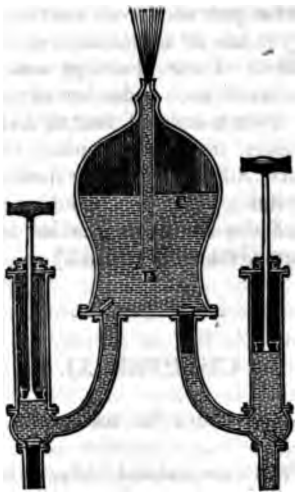
In laying pipes for a *jet d'eau*, the ascent of the water will be diminished, by any sudden angle in the tube; and the *ajutage* [jet of the fountain] must rise from the horizontal pipe, with a gentle sweep, or the jet will not reach so high as it ought to do, from calculating the height of the water in the reservoir. This circumstance explains the parabolic curve which the great artery takes in going off from the heart; it explains, also, why the branches of this great artery go off at different angles, and why, near the heart, the branch goes off at a greater angle from the direction of the stream.*

We have, perhaps, said enough to remove the notion, that there is any thing like irregularity in the course and distribution of the vessels of the living body. But there are some other laws of hydraulics, which give interest to

* This refers more especially to the intercostal arteries.

the structure and action of the circulating vessels. The elasticity of the coats of the artery, is a subject of importance in surgical pathology, and has very properly been deeply considered. This power has not, however, met with sufficient attention as one of the forces propelling the blood.

The law of inertia is easily comprehended, as it regards solids. Every thing about us proves, that it is more difficult to move a body, at rest, than to accelerate it, when it has been put in motion. The same law holds, of a column of water in a pipe: it is easier to keep it in motion, than to put it in motion from a state of rest. From this, it follows, that, in propelling water through a pipe, by a forcing-pump, as the impulse is given at intervals, and as the whole column is at rest after each stroke of the piston, much of the force must be lost. Now, if the heart contracted and propelled the blood into the artery, and there was then an interval of rest, during which the blood was stationary, the next pulsation of the heart would be, in part at least, exhausted, in bringing the blood from a state of rest into a state of motion. This will be best understood, by following the successive contrivances which the engineer has employed, in raising water, to keep the column in motion, uninterruptedly, and therefore to use his power in accelerating the stream, not in bringing it from a state of rest into a state of motion. The first idea was, to have two forcing-pipes, instead of one, so that one stroke should succeed another, without interval. But it was soon discovered, that there was a difficulty in adjusting, exactly, the two forces; and so it was found, that three forcing-pumps were better than two, as more effectually providing against any interruption to the motion of the stream; the second filling up the interval, between the impulse of the first and third. This multiplication of the parts of the engine shows the desire of the engineer to avoid interruption in the stream. But it does not so well illustrate our proper subject, as the next invention, which was, to employ an elastic power; and the engineer contrived it thus. A portion of air is confined in a reservoir; the pipes of two forcing-pumps are



ed into the reservoir, and they fill it half full of water; the mouth of the pipe, D, which is to convey away vater, reaches into the water in the reservoir. As vater rises, the air is compressed: so that, although umps act alternately, the elasticity of the contained cts uninterruptedly in pressing on the surface of the r, and raising it by the tube, D, in an equable stream. elasticity of the contained air, fills up the interval een the actions of the pumps, and admits of no inption to the force with which the water is propelled rds.

rely these are sufficient indications of the necessity ree powers acting in propelling the blood from the t. The first, is a sudden and powerful action of entricle: the second, is a contraction of the artery, what similar, excited by its distention: the third, gh a property independent of life, is a power permitno interval or alternation; it is the elasticity of the of the artery: and these three powers, duly adjusteep up a continued stream in the blood-vessels. It e, that when an artery is wounded, the blood flows

in pulses; but that proceeds from the regular acceleration of a jet, which yet has no actual interruption. Were not this continued flow of the blood provided, there would be a loss of power, at each pulsation of the heart, in carrying the blood from a state of rest to a state of motion; and if we consider how many pulses there are in the twenty-four hours, 80,000, we may make some estimate of the loss of vital power that would accrue had there been a neglect of the law of inertia in the apparatus of circulation.—SIR CHARLES BELL.]

CHAPTER XI.

OF THE ANIMAL STRUCTURE REGARDED AS A MASS.

CONTEMPLATING *an animal body*, in its collective capacity, we cannot forget to notice what a number of instruments are brought together, and often within how small a compass. It is a cluster of contrivances. In a canary-bird, for instance, and in the single ounce of matter which composes his body, (but which seems to be all employed,) we have instruments for eating, for digesting, for nourishment, for breathing, for generation, for running, for flying, for seeing, for hearing, for smelling: each appropriate—each entirely different from all the rest.

The human, or indeed the animal, frame, considered as a mass or assemblage, exhibits, in its composition, three properties, which have long struck my mind, as indubitable evidences, not only of design, but of a great deal of attention and accuracy, in prosecuting the design.

I. The first is, the exact correspondency of the two sides of the same animal: the right hand answering to the left, leg to leg, eye to eye, one side of the countenance to the other; and with a precision, to imitate which, in any tolerable degree, forms one of the difficulties of statuary, and requires, on the part of the artist, a constant attention to this property of his work, distinct from every other.

It is the most difficult thing that can be, to get a wig

made even; yet how seldom is the face awry! And what care is taken, that it should not be so, the anatomy of its bones demonstrates. The upper part of the face, is composed of thirteen bones, six on each side, answering each to each, and the thirteenth, without a fellow, in the middle. The lower part of the face, is in like manner composed of six bones, three on each side, respectively corresponding, and the lower jaw in the centre. In building an arch, could more be done in order to make the curve *true*—*i. e.*, the parts equidistant from the middle, alike in figure and position?

The exact resemblance of the *eyes*, considering how compounded this organ is in its structure, how various and how delicate are the shades of color with which its iris is tinged; how differently, as to effect upon appearance, the eye may be mounted in its socket; and how differently, in different heads, eyes actually are set—is a property of animal bodies much to be admired. Of ten thousand eyes, I do not know that it would be possible to match one, except with its own fellow; or to distribute them into suitable pairs, by any other selection than that which obtains.

This regularity of the animal structure, is rendered more remarkable by the three following considerations:—

1. The limbs, *separately* taken, have not this correlation of parts, but the contrary of it. A knife drawn down the chine, cuts the human body into two parts, externally equal and alike; you cannot draw a straight line which will divide a hand, a foot, the leg, the thigh, the cheek, the eye, the ear, into two parts equal and alike. Those parts which are placed upon the middle or partition line of the body, or which traverse that line—as the nose, the tongue, and the lips—may be so divided, or, more properly speaking, are double organs; but other parts cannot. This shows, that the correspondency, which we have been describing, does not arise by any necessity in the nature of the subject; for, if necessary, it would be universal; whereas it is observed only in the system or assemblage. It is not true of the separate parts: that is to say, it is found where it conduces to beauty or utility; it

is not found where it would subsist at the expense of both. The two wings of a bird, always correspond: the two sides of a feather, frequently do not. In centipedes, millepedes, and the whole tribe of insects, no two legs, on the same side, are alike; yet there is the most exact parity, between the legs opposite to one another.

2. The next circumstance to be remarked, is, that, whilst the cavities of the body are so configurated, as *externally* to exhibit the most exact correspondency of the opposite sides, the contents of these cavities have no such correspondency. A line drawn down the middle of the breast, divides the thorax into two sides, exactly similar; yet these two sides, enclose very different contents. The heart, lies on the left side; a lobe of the lungs, on the right; balancing each other, neither in size nor shape. The same thing holds of the abdomen. The liver, lies on the right side, without any similar viscus opposed to it, on the left. The spleen, indeed, is situated over-against the liver; but agreeing with the liver, neither in bulk nor form. There is no equipollency between these. The stomach, is a vessel, both irregular in its shape, and oblique in its position. The foldings and doublings of the intestines, do not present a parity of sides. Yet that symmetry, which depends upon the correlation of the sides, is externally preserved, throughout the whole trunk; and is the more remarkable in the lower parts of it, as the integuments are soft; and the shape, consequently, is not, as the thorax is by its ribs, reduced by natural stays. It is evident, therefore, that the external proportion does not arise from any equality, in the shape or pressure of the internal contents. What is it, indeed, but a correction of inequalities?—an adjustment, by mutual compensation, of anomalous forms into a regular congeries?—the effect, in a word, of artful, and, if we might be permitted so to speak, of studied collocation?

3. Similar also to this, is the third observation—that an internal inequality in the feeding vessels is so managed, as to produce no inequality of parts which were intended to correspond. The right arm, answers accurately to the left, both in size and shape; but the arterial branches,

which supply the two arms, do not go off from their trunk, in a pair, in the same manner, at the same place, or at the same angle. Under which want of similitude, it is very difficult to conceive how the same quantity of blood should be pushed through each artery; yet the result is right; the two limbs, which are nourished by them, perceive no difference of supply—no effects of excess or deficiency.

Concerning the difference of manner in which the subclavian and carotid arteries, upon the different sides of the body, separate themselves from the aorta, Cheselden seems to have thought, that the advantage which the left gain, by going off at an angle much more acute than the right, is made up to the right, by their going off together in one branch.* It is very possible that this may be the compensating contrivance; and if it be so, how curious—how hydrostatical!

II. Another perfection of the animal mass, is the *package*. I know nothing which is so surprising. Examine the contents of the trunk of any large animal. Take notice how soft, how tender, how intricate they are; how constantly in action, how necessary to life! Reflect upon the danger of any injury to their substance, any derangement of their position, any obstruction to their office. Observe the heart, pumping at the centre, at the rate of eighty strokes in a minute; one set of pipes carrying the steam away from it, another set bringing, in its course, the fluid back to it again; the lungs, performing their elaborate office, viz., distending and contracting their many thousand vesicles, by a reciprocation, which cannot cease for a minute; the stomach, exercising its powerful chemistry; the bowels, silently propelling the changed aliment, collecting from it, as it proceeds, and transmitting to the blood, an incessant supply of prepared and assimilated nourishment; that blood, pursuing its course; the liver, the kidneys, the pancreas, the parotid, with many other known and distinguishable glands, drawing off from it, all the while, their proper secretions. These several operations, together with others, more subtile but less capable of being investigated, are going on within us, at one and

* Ches. Anat. p. 184, ed. 7.

the same time. Think of this; and then observe how the body itself, the case which holds this machinery, is rolled, and jolted, and tossed about, the mechanism remaining unhurt, and with very little molestation even of its nicest motions. Observe a rope-dancer, a tumbler, or a monkey; the sudden inversions and contortions which the internal parts sustain by the postures into which their bodies are thrown; or rather observe the shocks which these parts, even in ordinary subjects, sometimes receive from falls and bruises, or by abrupt jerks and twists, without sensible or with soon-recovered damage. Observe this, and then reflect, how firmly every part must be secured, how carefully surrounded, how well tied down and packed together.

This property of animal bodies, has never, I think, been considered under a distinct head, or so fully as it deserves. I may be allowed therefore, in order to verify my observation concerning it, to set forth a short anatomical detail, though it oblige me to use more technical language than I should wish to introduce into a work of this kind.

1. The *heart* (such care is taken of the centre of life) is placed between two soft lobes of the lungs; is *tied* to the mediastinum and to the pericardium; which pericardium is not only itself an exceedingly strong membrane, but *adheres* firmly to the duplicature of the mediastinum, and, by its point, to the middle tendon of the diaphragm. The heart is also *sustained* in its place, by the great blood-vessels which issue from it.*

2. The *lungs* are *tied* to the sternum, by the mediastinum before; to the vertebræ, by the pleura behind. It seems, indeed, to be the very use of the mediastinum, (which is a membrane that goes straight through the middle of the thorax, from the breast to the back,) to keep the contents of the thorax in their places; in particular to hinder one lobe of the lungs from incommoding another, or the parts of the lungs from pressing upon each other, when we lie on one side.†

3. The *liver* is fastened in the body by two ligaments; the first, which is large and strong, comes from the covering of the diaphragm, and penetrates the substance of

* Keill's Anat. p. 107, ed. 3. † Ib. p. 119, ed. 3.

the liver; the second, is the umbilical vein, which, after birth, degenerates into a ligament. The first, which is the principal, fixes the liver in its situation, whilst the body holds an erect posture; the second, prevents it from pressing upon the diaphragm, when we lie down; and both together, *sling* or suspend the liver, when we lie upon our backs, so that it may not compress or obstruct the ascending vena cava,* to which belongs the important office of returning the blood, from the body to the heart.

4. The *bladder*, is tied to the navel, by the urachus, transformed into a ligament: thus, what was a passage for urine, to the fœtus, becomes, after birth, a support or stay to the bladder. The peritonæum also keeps the viscera from confounding themselves with, or pressing irregularly upon, the bladder; for the kidneys and bladder are contained in a distinct duplicature of that membrane, being thereby partitioned off from the other contents of the abdomen.

5. The *kidneys*, are lodged in a bed of fat.

6. The *pancreas*, or sweetbread, is strongly tied to the peritonæum, which is the great wrapping sheet, that encloses all the bowels contained in the lower belly.†

7. The *spleen*, also, is confined to its place by an adhesion to the peritonæum and diaphragm, and by a connexion with the omentum.‡ It is possible, in my opinion, that the spleen may be merely a *stuffing*, a soft cushion to fill up a vacancy or hollow, which, unless occupied, would leave the package loose and unsteady: for, supposing that it answers no other purpose than this, it must be vascular, and admit of a circulation through it, in order to be kept alive, or be a part of a living body.[32]

8. The *omentum*, epiplöon, or caul, is an apron tucked up, or doubling upon itself, at its lowest part. The upper edge is tied to the bottom of the stomach, to the spleen,

[32] Our author has not failed to fall into the snare which lies in the path of the adventurous theorist. We have here a new theory of the spleen. The spleen in truth has a double office: it is ever found attached to the digesting part of the intestinal canal; and is reasonably considered to afford occasional increase of circulation to the stomach, and to supply blood to the liver of that quality which appears necessary to a copious secretion of bile.—ENG. ED.

* Ches. Anat. p. 162. † Keill's Anat. p. 57. ‡ Ches. Anat. p. 167.

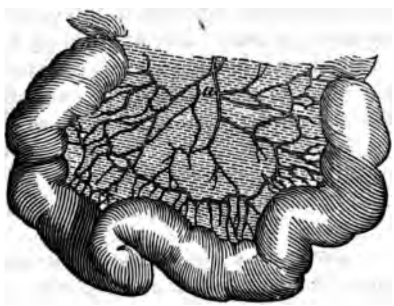
as hath already been observed, and to part of the duodenum. The reflected edge, also, after forming the doubling, comes up behind the front flap, and is tied to the colon and adjoining viscera.*

9. The septa of the brain, probably prevent one part of that organ from pressing with too great a weight upon another part. The processes of the dura mater, divide the cavity of the skull, like so many inner partition walls, and thereby confine each hemisphere and lobe of the brain, to the chamber which is assigned to it, without its being liable to rest upon, or intermix with, the neighboring parts. The great art and caution of packing, is, to prevent one thing hurting another. This, in the head, the chest, and the abdomen, of an animal body, is, amongst other methods, provided for by membranous partitions and wrappings, which keep the parts separate.

The above may serve as a short account of the manner in which the principal viscera are sustained in their places. But of the provisions for this purpose, by far, in my opinion, the most curious, and where also such a provision was most wanted, is in the *guts*. It is pretty evident, that a long narrow tube, (in man, about five times the length of the body,) laid from side to side, in folds upon one another, winding in oblique and circuitous directions, composed also of a soft and yielding substance, must, without some extraordinary precaution for its safety, be continually displaced, by the various, sudden, and abrupt motions of the body which contains it. I should expect that, if not bruised or wounded by every fall, or leap, or twist, it would be entangled, or be involved with itself; or, at the least, slipped and shaken out of the order in which it is disposed, and which order is necessary to be preserved, for the carrying on of the important functions which it has to execute in the animal economy. Let us see, therefore, how a danger so serious, and yet so natural to the length, narrowness, and tubular form of the part, is provided against. The expedient is admirable; and it is this. The intestinal canal, throughout its whole process, is knit to the edge of a broad fat membrane, called the mesentery. It forms the margin of this mesentery, being stitched and

* Ches. Anat. p. 167.

fastened to it, like the edging of a ruffle : being four times as long as the mesentery itself, it is what a sempstress would call "puckered or gathered on" to it. This is the nature of the connexion of the gut with the mesentery; and being thus joined to, or rather made a part of, the mesentery, it is folded and wrapped up together with it. Now the mesentery, having a considerable dimension in breadth, being in its substance, withal, both thick and suety, is capable of a close and safe folding, in comparison of what the intestinal tube would admit of, if it had remained loose. . The mesentery, likewise, not only keeps the intestinal canal in its proper place and position, under all the turns and windings of its course, but sustains the numberless small vessels, the arteries, the veins, the lympheducts, and, above all, the lacteals, which lead from or to almost every point of its coats and cavity. This membrane, which appears to be the



great support and security of the alimentary apparatus, is itself strongly tied to the first three vertebræ of the loins.*

III. A third general property of animal forms, is *beauty*. I do not mean relative beauty, or that of one individual above another of the same species, or of one species compared with another species; but I mean, generally, the provision which is made in the body of almost every animal to adapt its appearance to the perception of the animals with which it converses. In our own species, for example, only consider what the parts and materials are of which the fairest body is composed; and no further observation will be necessary to show how

* Keill's Anat. p. 45.

well these things are wrapped up, so as to form a mass which shall be capable of symmetry in its proportion, and of beauty in its aspect; how the bones are covered, the bowels concealed, the roughnesses of the muscle smoothed and softened; and how over the whole is drawn an integument, which converts the disgusting materials of a dissecting-room into an object of attraction to the sight, or one upon which it rests, at least with ease and satisfaction. Much of this effect, is to be attributed to the intervention of the cellular or adipose membrane, which lies immediately under the skin; is a kind of lining to it; is moist, soft, slippery, and compressible; every where filling up the interstices of the muscles, and forming thereby their roundness and flowing line, as well as the evenness and polish of the whole surface.

All which seems to be a strong indication of design, and of a design studiously directed to this purpose. And it being once allowed that such a purpose existed with respect to *any* of the productions of Nature, we may refer, with a considerable degree of probability, other particulars to the same intention; such as the tints of flowers, the plumage of birds, the furs of beasts, the bright scales of fishes, the painted wings of butterflies and beetles, the rich colors and spotted lustre of many tribes of insects.

There are parts, also, of animals, ornamental, and the properties, by which they are so, not subservient, that we know of, to any other purpose. The *irides* of most animals are very beautiful, without conducing at all, by their beauty, to the perfection of vision; and Nature could in no part have employed her pencil to so much advantage, because no part presents itself so conspicuously to the observer, or communicates so great an effect to the whole aspect.

In plants, especially in the flowers of plants, the principle of beauty holds a still more considerable place in their composition; is still more confessed than in animals. Why, for one instance, out of a thousand, does the corolla of the tulip, when advanced to its size and maturity, *change* its color? The purposes, so far as we can see, of vegetable nutrition might have been carried on as well

by its continuing green. Or, if this could not be, consistently with the progress of vegetable life, why break into such a variety of colors? This is no proper effect of age, or of declension in the ascent of the sap; for that, like the autumnal tints, would have produced one color on one leaf, with marks of fading and withering. It seems a lame account to call it, as it has been called, a disease of the plant. Is it not more probable that this property, which is independent, as it should seem, of the wants and utilities of the plant, was calculated for beauty, intended for display?

A ground, I know, of objection has been taken against the whole topic of argument, namely, that there is no such thing as beauty at all; in other words, that whatever is useful and familiar comes of course to be thought beautiful; and that things appear to be so, only by their alliance with these qualities. Our idea of beauty is capable of being in so great a degree modified by habit, by fashion, by the experience of advantage or pleasure, and by associations arising out of that experience, that a question has been made, whether it be not altogether generated by these causes, or would have any proper existence without them. It seems, however, a carrying of the conclusion too far, to deny the existence of the principle, viz., a native capacity of perceiving beauty, on account of an influence, or of varieties proceeding from that influence, to which it is subject, seeing that principles the most acknowledged are liable to be affected in the same manner. I should rather argue thus:—The question respects objects of sight. Now every other sense hath its distinction of agreeable and disagreeable. Some tastes offend the palate, others gratify it. In brutes and insects, this distinction is stronger and more regular than in man. Every horse, ox, sheep, swine, when at liberty to choose, and when in a natural state, that is, when not vitiated by habits forced upon it, eats and rejects the same plants. Many insects, which feed upon particular plants, will rather die than change their appropriate leaf. All this, looks like a determination in *the sense itself* to particular tastes. In like manner,

smells affect the nose with sensations pleasurable or disgusting. Some sounds, or compositions of sound, delight the ear: others torture it. Habit can do much in all these cases, (and it is well for us that it can; for it is this power which reconciles us to many necessities:) but has the distinction, in the mean time, of agreeable and disagreeable, no foundation in the sense itself? What is true of the other senses, is most probably true of the eye, (the analogy is irresistible,) viz., that there belongs to it an original constitution, fitted to receive pleasure from some impressions, and pain from others.

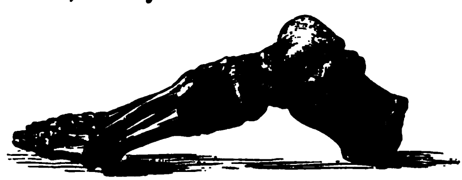
I do not however know, that the argument, which alleges beauty as a final cause, rests upon this concession. We possess a sense of beauty, however we come by it. It in fact exists. Things are not indifferent to this sense; all objects do not suit it; many, which we see, are agreeable to it: many others disagreeable. It is certainly not the effect of habit upon the particular object, because the most agreeable objects are often the most rare; many which are very common, continue to be offensive. If they be made supportable by habit, it is all which habit can do; they never become agreeable. If this sense, therefore, be acquired, it is a result: the produce of numerous and complicated actions of external objects upon the senses, and of the mind upon its sensations. With this *result*, there must be a certain congruity, to enable any particular object to please; and that congruity, we contend, is consulted in the *aspect* which is given to animal and vegetable bodies.

IV. The skin and covering of animals, is that upon which their appearance chiefly depends; and it is that part, which, perhaps, in all animals, is most decorated, and most free from impurities. But were beauty, or agreeableness of aspect, entirely out of the question, there is another purpose answered by this integument, and by the collocation of the parts of the body beneath it, which is of still greater importance; and that purpose is *concealment*. Were it possible to view through the skin the mechanism of our bodies, the sight would frighten us out of our wits. "Durst we make a single move-

ment," asks a lively French writer, "or stir a step from the place we were in, if we *saw* our blood circulating, the tendons pulling, the lungs blowing, the humors filtrating, and all the incomprehensible assemblage of fibres, tubes, pumps, valves, currents, pivots, which sustain an existence at once so frail and so presumptuous?"

V. Of animal bodies, considered as masses, there is another property, more curious than it is generally thought to be; which is the faculty of *standing*: and it is more remarkable in two-legged animals than in quadrupeds, and, most of all, as being the tallest, and resting upon the smallest base, in man. There is more, I think, in the matter than we are aware of. The statue of a man, placed loosely upon a pedestal, would not be secure of standing half an hour. You are obliged to fix its feet to the block, by bolts and solder; or the first shake, the first gust of wind, is sure to throw it down. Yet this statue shall express all the mechanical proportions of a living model. It is not, therefore, the mere figure, or merely placing the centre of gravity within the base, that is sufficient. Either the law of gravitation is suspended, in favor of living substances, or something more is done for them, in order to enable them to uphold their posture. There is no reason whatever to doubt, but that their parts descend by gravitation, in the same manner as those of dead matter. The gift, therefore, appears to me to consist, in a faculty of perpetually shifting the centre of gravity, by a set of obscure, indeed, but of quick-balancing, actions, so as to keep the line of direction, which is a line drawn from that centre to the ground, within its prescribed limits. Of these actions, it may be observed, first, that they in part constitute what we call strength. The dead body drops down. The mere adjustment, therefore, of weight and pressure, which may be the same the moment after death, as the moment before, does not support the column. In cases also of extreme weakness, the patient cannot stand upright. Secondly, that these actions are only in a small degree voluntary. A man is seldom conscious of his voluntary powers in keeping himself upon his legs. A child

learning to walk, is the greatest posture-master in the world: but art, if it may be so called, sinks into habit; and he is soon able to poise himself in a great variety of attitudes, without being sensible either of caution or effort. But still, there must be an aptitude of parts, upon which habit can thus attach; a previous capacity of motions which the animal is thus taught to exercise: and the facility with which this exercise is acquired forms one object of our admiration. What parts are principally employed, or in what manner each contributes to its office, is, as hath already been confessed, difficult to explain. Perhaps the obscure motion of the bones of the feet, may have their share in this effect. They are put in action, by every slip or vacillation of the body, and seem to assist in restoring its balance. Certain it is, that this circumstance, in the structure of the foot, viz., its being composed of many small bones, applied to and articulating with one another by diversely-shaped surfaces, instead of being made of one piece, like the last of a shoe, is very remarkable.



I suppose also that it would be difficult to stand firmly upon stilts or wooden legs, though their base exactly imitated the figure and dimensions of the sole of the foot. The alternation of the joints, the knee-joint bending backward, the hip-joint forward; the flexibility, in every direction, of the spine, especially in the loins and neck, appear to be of great moment in preserving the equilibrium of the body. With respect to this last circumstance, it is observable, that the vertebræ are so confined by ligaments as to allow no more slipping upon their bases, than what is just sufficient to break the shock which any violent motion may occasion to the body. A certain degree also of tension of the sinews appears to be essential to an

erect posture: for it is by the loss of this, that the dead or paralytic body drops down. The whole is a wonderful result of combined powers, and of very complicated operations. Indeed, that *standing* is not so simple a business, as we imagine it to be, is evident from the strange gesticulations of a drunken man, who has lost the government of the centre of gravity.[33]

We have said, that this property is the most worthy of observation in the *human* body; but a *bird*, resting upon its perch, or hopping upon a spray, affords no mean specimen of the same faculty. A chicken runs off as soon as it is hatched from the egg; yet a chicken, considered geometrically, and with relation to its centre of gravity, its line of direction, and its equilibrium, is a very irregular solid. Is this gift, therefore, or instruction? May it not be said to be with great attention, that Nature hath balanced the body upon its pivots?

I observe also in the same *bird*, a piece of useful mechanism of this kind. In the trussing of a fowl, upon bending the legs and thighs up towards the body, the cook finds that the claws close, of their own accord. Now let it be remembered, that this is the position of the limbs, in which the bird rests upon its perch. And in this position, it sleeps in safety; for the claws do their office in keeping hold of the support—not by any exertion of voluntary power, which sleep might suspend, but by

[33] All this is admirably well put by our author. Yet when he says "the gift consists in the faculty of perpetually shifting the centre of gravity, by a set of obscure, indeed, but of quick-balancing actions," he states a fact, but omits the most surprising circumstance of all. No doubt such efforts are made; but what directs them? If a man should balance a staff, resting it on the point of the finger, he shifts the finger continually, in doing which he is directed by the eye—he sees the staff inclining. How does a man judge of the inclination of his body in the very first degree of deviation from the perpendicular? He does not see himself, nor is he directed by the objects around him, since a blind man will stand as securely as one who sees. The fact is, that he has a knowledge of muscular action—a sensibility to the finest adjustment of the muscles, by which he directs their efforts. This sense is of all the most marvellous: a sensibility to an internal motion, more minute and curious than are the sensibilities to external impression; and which, as may be easily proved, ministers to a variety of properties in the living body, and especially to the organs of sense themselves.—*Eng. Ed.*

the traction of the tendons, in consequence of the attitude which the legs and thighs take, by the bird sitting down, and to which the mere weight of the body gives the force that is necessary.

VI. Regarding the human body as a mass; regarding the general conformations which obtain in it; regarding also particular parts in respect to those conformations; we shall be led to observe what I call "interrupted analogies." The following, are examples of what I mean by these terms; and I do not know how such critical deviations can, by any possible hypothesis, be accounted for, without design.

1. All the bones of the body are covered with a *periosteum*, except the teeth, where it ceases, and enamel of ivory, which saws and files will hardly touch, comes into its place. No one can doubt of the use and propriety of this difference; of the "analogy" being thus "interrupted;" of the rule, which belongs to the conformation of the bones, stopping where it does stop; for, had so exquisitely sensible a membrane as the periosteum invested the teeth, as it invests every other bone of the body, their action, necessary exposure, and irritation, would have subjected the animal to continual pain. General as it is, it was not the sort of integument which suited the teeth; what they stood in need of, was, a strong, hard, insensible, defensive coat; and exactly such a covering is given to them, in the ivory enamel which adheres to their surface.

2. The scarf-skin, which clothes all the rest of the body, gives way, at the extremities of the toes and fingers, to *nails*. A man has only to look at his hand, to observe with what nicety and precision that covering, which extends over every other part, is here superseded by a different substance and a different texture. Now, if either the rule had been necessary, or the deviation from it accidental, this effect would not be seen. When I speak of the rule being necessary, I mean, the formation of the skin upon the surface being produced by a set of causes constituted without design, and acting, as all ignorant causes must act, by a general operation. Were this the case, no account could be given of the operation being suspended at the fingers' ends, or on the back part of the fingers, and

not on the fore part. On the other hand: if the deviation were accidental, an error, an anomalism—were it any thing else than settled by intention—we should meet with nails upon other parts of the body; they would be scattered over the surface, like warts or pimples.[34]

3. All the great cavities of the body are enclosed by membranes, except the *skull*. Why should not the brain be content with the same covering as that which serves for the other principal organs of the body? The heart, the lungs, the liver, the stomach, the bowels, have all soft integuments, and nothing else. The muscular coats, are all soft and membranous. I can see a reason for this distinction in the final cause, but in no other. The importance of the brain to life, (which experience proves to be immediate,) and the extreme tenderness of its substance, make a solid case more necessary for it, than for any other part; and such a case the hardness of the skull supplies. When the smallest portion of this natural casket is lost, how carefully, yet how imperfectly, is it replaced by a plate of metal! If an anatomist should say, that this bony protection is not confined to the brain, but is extended along the course of the spine, I answer, that he adds strength to the argument. If he remark, that the chest also is fortified by bones, I reply, that I should have alleged this instance myself, if the ribs had not appeared subservient to the purpose of motion, as well as of defence. What distinguishes the skull from every other cavity is, that the bony covering completely surrounds its contents, and is calculated, not for motion, but solely for

[34] The human nail is calculated to support the cushion of the extremity of the finger, and is important to us in grasping or holding any thing; but more so still in sustaining that cushion as the chief organ of touch. There are other parts of the body which have exquisite sensibility, yet they are not provided so as to give us that information of the condition of matter which we have through the finger, and in a lesser degree through the whole inner surface of the hand. We easily feel, for example, the pulsation of the artery at the wrist, through the combination of the sensibility of the nerve of touch with the elastic cushion of the finger. The best proof of the use of the elastic cushion is this:—Although the tip of the tongue feels so exquisitely that the presence of a hair of wool troubles us, yet if we apply it to the pulse we shall not be sensible of the beat.—Eng. Ed.

defence. Those hollows, likewise, and inequalities, which we observe in the inside of the skull, and which exactly fit the folds of the brain, answer the important design of keeping the substance of the brain steady, and of guarding it against concussions.

CHAPTER XII.

COMPARATIVE ANATOMY.

WHENEVER we find a general plan pursued, yet with such variations in it, as are, in each case, required by the particular exigency of the subject to which it is applied, we possess, in such a plan, and such adaptation, the strongest evidence that can be afforded of intelligence and design; an evidence which the most completely excludes every other hypothesis. If the general plan proceeded from any fixed necessity in the nature of things, how could it accommodate itself to the various wants and uses which it had to serve under different circumstances, and on different occasions? *Arkwright's* mill was invented for the spinning of cotton. We see it employed for the spinning of wool, flax, and hemp, with such modifications of the original principle, such variety in the same plan, as the texture of those different materials rendered necessary. Of the machine's being put together with design, if it were possible to doubt, whilst we saw it only under one mode, and in one form, when we came to observe it in its different applications, with such changes of structure, such additions and supplements, as the special and particular use, in each case, demanded, we could not refuse any longer our assent to the proposition—"that intelligence, properly and strictly so called, (including under that name, foresight, consideration, reference to utility,) had been employed, as well in the primitive plan, as in the several changes and accommodations which it is made to undergo."

Very much of this reasoning is applicable to what has

been called *Comparative Anatomy.* In their general economy, in the outlines of the plan, in the construction as well as offices of their principal parts, there exists between all large terrestrial animals a close resemblance. In all, life is sustained, and the body nourished, by nearly the same apparatus. The heart, the lungs, the stomach, the liver, the kidneys, are much alike in all. The same fluid (for no distinction of blood has been observed) circulates through their vessels, and nearly in the same order. The same cause, therefore, whatever that cause was, has been concerned in the origin, has governed the production, of these different animal forms.

When we pass on to smaller animals, or to the inhabitants of a different element, the resemblance becomes more distant and more obscure ; but still the plan accompanies us.

And, what we can never enough commend, and which it is our business at present to exemplify, the plan is attended, through all its varieties and deflections, by subserviences to special occasions and utilities.

I. The *covering* of different animals, (though whether I am correct in classing this under their anatomy, I do not know,) is the first thing which presents itself to our observation ; and is, in truth, both for its variety and its suitableness to their several natures, as much to be admired as any part of their structure. We have bristles, hair, wool, furs, feathers, quills, prickles, scales ; yet in this diversity, both of material and form, we cannot change one animal's coat for another, without evidently changing it for the worse ;—taking care, however, to remark, that these coverings are, in many cases, armor as well as clothing ; intended for protection, as well as warmth.

The *human* animal is the only one which is naked, and the only one which can clothe itself. This is one of the properties which renders him an animal of all climates, and of all seasons. He can adapt the warmth or lightness of his covering to the temperature of his habitation. Had he been born with a fleece upon his back, although he might have been comforted by its warmth in high latitudes, it would have oppressed him by its weight and heat, as the species spread towards the equator.

What art, however, does for men, Nature has, in many instances, done for those animals which are incapable of art. Their clothing, of its own accord, changes with their necessities. This is particularly the case with that large tribe of quadrupeds which are covered with *furs*. Every dealer in hare-skins and rabbit-skins knows how much the fur is thickened by the approach of winter. It seems to be a part of the same constitution and the same design, that wool, in hot countries, degenerates, as it is called, but in truth (most happily for the animal's ease) passes into hair; whilst, on the contrary, that hair, in the dogs of the polar regions, is turned into wool, or something very like it. To which may be referred, what naturalists have remarked, that bears, wolves, foxes, hares, which do not take the water, have the fur much thicker on the back than the belly; whereas, in the beaver, it is the thickest upon the belly; as are the feathers in waterfowl. We know the final cause of all this, and we know no other.

The *covering of birds* cannot escape the most vulgar observation: its lightness, its smoothness, its warmth; the disposition of the feathers, all inclined backward, the down about their stem, the overlapping of their tips, their different configuration in different parts, not to mention the variety of their colors, constitute a vestment for the body, so beautiful, and so appropriate to the life which the animal is to lead, as that, I think, we should have had no conception of any thing equally perfect, if we had never seen it, or can now imagine any thing more so. Let us suppose (what is possible only in supposition) a person who had never seen a bird, to be presented with a plucked pheasant, and bid to set his wits to work how to contrive for it a covering which shall unite the qualities of warmth, levity, and least resistance to the air, and the highest degree of each; giving it also as much of beauty and ornament as he could afford. He is the person to behold the work of the Deity, in this part of his creation, with the sentiments which are due to it.

The commendation which the general aspect of the feathered world seldom fails of exciting, will be increased

by further examination. It is one of those cases in which the philosopher has more to admire than the common observer. Every *feather* is a mechanical wonder. If we look at the quill, we find properties not easily brought together, strength and lightness. I know few things more remarkable than the strength and lightness of the very pen with which I am writing. If we cast our eye to the upper part of the stem, we see a material, made for the purpose, used in no other class of animals, and in no other part of birds, tough, light, pliant, elastic. The pith also, which feeds the feathers, is, amongst animal substances, *sui generis*—neither bone, flesh, membrane, nor tendon.*

But the artificial part of a feather, is the *beard*, or, as it is sometimes, I believe, called, the vane. By the beards, are meant what are fastened on each side of the stem, and what constitute the breadth of the feather, what we usually strip off from one side, or both, when we make a pen. The separate pieces, or laminæ, of which the beard is composed, are called threads, sometimes filaments or rays. Now, the first thing which an attentive observer will remark, is, how much stronger the beard of the feather shows itself to be, when pressed in a direction perpendicular to its plane, than when rubbed, either up or down, in the line of the stem; and he will soon discover the structure which occasions this difference, viz., that the laminæ, whereof these beards are composed, are flat, and placed with their flat sides towards each other, by which means, whilst they *easily* bend for the approaching of each other, as any one may perceive by drawing his finger ever so lightly upwards, they are much harder to bend out of their plane, which is the direction in which they have to encounter the impulse and pressure of the air, and in which their strength is wanted, and put to the trial.

This is one particularity, in the structure of a feather: a second, is still more extraordinary. Whoever examines a feather, cannot help taking notice, that the threads, or

* The quill part of a feather is composed of circular and longitudinal fibres. In making a pen, you must scrape off the coat of circular fibres, or the quill will split in a ragged, jagged manner, making what boys call *cat's teeth*.

laminæ, of which we have been speaking, in their natural state, *unite*; that their union is something more than the mere apposition of loose surfaces; that they are not parted asunder without some degree of force; that, nevertheless, there is no glutinous cohesion between them; that, therefore, by some mechanical means or other, they catch or clasp among themselves, thereby giving to the beard or vane its closeness and compactness of texture. Nor is this all: when two laminæ which have been separated by accident or force are brought together again, they immediately *reclasp*; the connexion, whatever it was, is perfectly recovered, and the beard of the feather becomes as smooth and firm, as if nothing had happened to it. Draw your finger down the feather, which is against the grain, and you break, probably, the junction of some of the contiguous threads: draw your finger up the feather, and you restore all things to their former state. This is no common contrivance; and now for the mechanism by which it is effected. The threads or laminæ above-mentioned, are *interlaced* with one another; and the interlacing is performed by means of a vast number of fibres or teeth, which the laminæ shoot forth, *on each side*, and which hook and grapple together. A friend of mine counted fifty of these fibres in one-twentieth of an inch. These fibres are crooked, but curved after a different manner; for those, which proceed from the thread on the side, towards the extremity of the feather, are longer, more flexible, and bent downward: whereas those which proceed from the side towards the beginning or quill-end of the feather, are shorter, firmer, and turn upwards. The process, then, which takes place, is as follows: when two laminæ are pressed together, so that these long fibres are forced far enough over the short ones, their crooked parts fall into the cavity made by the crooked parts of the others, just as the latch that is fastened to a door enters into the cavity of the catch fixed to the door-post, and there hooking itself, fastens the door; for it is properly in this manner that one thread of a feather is fastened to the other.

This admirable structure of the feather, which it is

easy to see with the microscope, succeeds perfectly for the use to which Nature has designed it, which use was, not only that the laminæ might be united, but that, when one thread or laminæ has been separated from another, by some external violence, it might be reclasped with sufficient facility and expedition.*

In the *ostrich*, this apparatus of crotchets and fibres, of hooks and teeth, is wanting; and we see the consequence of the want. The filaments hang loose and separate from one another, forming only a kind of down; which constitution of the feathers, however it may fit them for the flowing honors of a lady's head-dress, may be reckoned an imperfection in the bird, inasmuch as wings composed of these feathers, although they may greatly assist it in running, do not serve for flight.

But, under the present division of our subject, our business with feathers is, as they are the *covering* of the bird. And herein a singular circumstance occurs. In the small order of birds which winter with us, from the snipe downwards, let the external color of the feathers be what it will, their Creator has universally given them a bed of *black* down next their bodies. Black, we know, is the warmest color: and the purpose here is, to *keep in* the heat arising from the heart and circulation of the blood.[35]

[35] When we attempt to apply the lights of experimental philosophy to this subject, the inquiry is not a little embarrassing. A loose woolly texture, or down, as it implies the presence of air in its interstices, air being a bad conductor of heat, is therefore a warm covering: it prevents the expenditure of animal heat. When we consider the coverings of birds, we must take new elements into our process of reasoning; we must reflect on the effects of the conduction and radiation of heat. The conduction is the conveyance of heat; and the radiation is the parting with it into the atmosphere or into space. We have already explained why the interior covering of the arctic bird should be loose: as to the color, its effect must result from radiation. It appears (to use the vulgar language) that the influence of cold both on quadrupeds and birds is to increase their woolly or downy covering, and, in many instances, to change their exterior color to white: in other and more correct words, a provision is made for changing their clothing so as to suit their altered circumstances. This change of color corresponds with philosophical experiments—a white surface absorbing the least,

* The above account is taken from Memoirs for a Natural History of Animals, by the Royal Academy of Paris, published in 1701, p. 219.

It is further likewise remarkable, that this is not found in larger birds; for which there is also a reason. Small birds are much more exposed to the cold than large ones, forasmuch as they present, in proportion to their bulk, a much larger surface to the air. If a turkey were divided into a number of wrens, (supposing the shape of the turkey and the wren to be similar,) the surface of all the wrens would exceed the surface of the turkey, in the proportion of the length, breadth, (or of any homologous line,) of a turkey to that of a wren, which would be perhaps a proportion of ten to one. It was necessary, therefore, that small birds should be more warmly clad than large ones; and this seems to be the expedient by which that exigency is provided for.

II. In comparing different animals, I know no part of their structure which exhibits greater variety, or, in that variety, a nicer accommodation to their respective conveniency, than that which is seen in the different formations of their *mouths*. Whether the purpose be the reception of aliment, merely, or the catching of prey, the picking up of seeds, the cropping of herbage, the extraction of juices, the suction of liquids, the breaking and grinding of food, the taste of that food, together with the respiration of air, and, in conjunction with it, the utterance of sound; these various offices are assigned to this one part, and, in different species, provided for, as they are wanted, by its different constitution. In the human species, forasmuch as there are hands to convey the food to the mouth, the mouth is flat, and by reason of its flatness, fitted only for *reception*; whereas the projecting jaws, the wide rictus, the pointed teeth of the dog and his affinities, enable them to apply their mouths to *snatch and seize* the objects of their pursuit. The full lips, the rough tongue, the corrugated cartilaginous palate, the broad cutting teeth of the ox, the deer, the horse, and the sheep, qualify this tribe for *browsing* upon their pasture; either gathering large mouthfuls at once, where the grass is long, which is the case with

and radiating the least, it should therefore tend to confine the vital heat within the animal, and carry it off slowly to the atmosphere.—*Eng. Ed.*

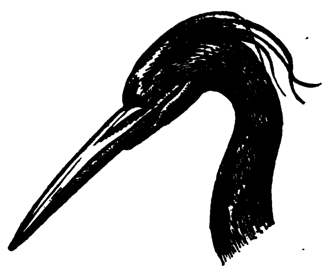
the ox, in particular, or biting close where it is short, which the horse and the sheep are able to do, in a degree that one could hardly expect. The retired under-jaw of a swine, *works in the ground*, after the protruding snout, like a prong or ploughshare, has made its way to the roots upon which it feeds. A conformation so happy was not the gift of chance.

In *birds*, this organ assumes a new character; new, both in substance and in form, but in both wonderfully adapted to the wants and uses of a distinct mode of existence. We have no longer the fleshy lips, the teeth of enamelled bone; but we have, in the place of these two parts, and to perform the office of both, a hard substance, (of the same nature with that which composes the nails, claws, and hoofs of quadrupeds,) cut out into proper shapes, and mechanically suited to the actions which are wanted. The sharp edge and tempered point of the *sparrow's* bill, picks almost every kind of seed from its concealment in the plant, and not only so, but hulls the grain, breaks and shatters the coats of the seed, in order to get at the kernel. The hooked beak of the hawk tribe, separates the flesh from the bones of the animals which it feeds upon, almost with the cleanness and precision of a dissector's knife. The butcher-bird transfixes its prey upon the spike of a thorn whilst it picks its bones. In

some birds of this class, we have the *cross* bill, *i. e.*, both the upper and lower bill hooked, and their tips crossing. The *spoon* bill, enables the goose to graze, to collect its food from the bottom of pools, or to seek it amidst the soft or liquid substances with which it is mixed. The *long* tapering bill of the snipe and woodcock, penetrates still deeper into moist earth, which is the bed in which the food of that species is lodged. This is exactly the instrument which the animal wanted. It did not want strength in its bill, which was inconsistent with the slender form of the animal's neck, as well as unnecessary for the kind of aliment upon which it subsists ; but it wanted length to reach its object.[36]

But the species of bill, which belongs to the birds that live by *suction*, deserves to be described in its relation to

[36] With the instrument, as we have before hinted, we should expect a particular instinctive action, and a corresponding muscular power. As an animal with horns has a powerful neck, so has the neck of the heron, which is introduced here, an extraordinary muscular power, without which, indeed, the long and sharp bill would be of little use. When the dog approaches the wounded heron, the bird throws itself upon its back, and, retracting its long neck, suddenly darts it out with a force which strikes the bill deep into the dog. If you hold your hat



towards the bird, the bill will be struck quite through it. In contending with the hawk, when the latter is spitted, it is not by the rapid descent of the hawk, but by the force with which the heron drives its bill.

The strength of the bill of the parrot, and that of all birds which break the stones of fruit, or nuts, or hard seeds, is in another direction : the bill is hooked, yet is differently formed from that of the carnivorous bird. The intention is, in the first place, that the point shall

that office. They are what naturalists call serrated or dentated bills; the inside of them, towards the edge, being thickly set with parallel or concentric rows of short, strong, sharp-pointed prickles. These, though they should be called teeth, are not for the purpose of mastication, like the teeth of quadrupeds; nor yet, as in fish, for the seizing and retaining of their prey; but for a quite different use. They form a filter. The *duck*, by means of them, discusses the mud; examining with great accuracy the puddle, the brake, every mixture which is likely to contain her food. The operation is thus carried on:—The

play vertically, which, with the strengthening of successive layers near the point, enables it to break hard materials; and secondly, that by this form the nut or seed may be brought nearer the joining or articulation of the jaw, which gives the same advantage that we have when we put a nut nearer the joint of the nut-cracker, that is, nearer the fulcrum.

One disadvantage of this form and shortness of the bill would be, that the mandibles could not open wide enough to take in a large seed; but it is provided that the upper mandible shall move upon the skull as well as the lower one, a subject which has not escaped our author's attention.

The form of the bill of the cross-bill, which he mentions, looks like an imperfection, but is attended with real advantages. It is not for crushing, but rather for splitting up a seed into halves, and tearing the cones of the fir-tree.

One of the most curious provisions is in the bill of the sea-crow. The mandibles are compressed into the form of simple laminæ, and the lower mandible projects beyond the upper one; so that, as he skims along the water, he dips his bill and lifts his food by the most appropriate instrument.—Eng. Ed.

liquid or semiliquid substances in which the animal has plunged her bill, she draws, by the action of her lungs, through the narrow interstices which lie between these teeth, catching, as the stream passes across her beak, whatever it may happen to bring along with it, that proves agreeable to her choice, and easily dismissing all the rest. Now, suppose the purpose to have been, out of a mass of confused and heterogeneous substances, to separate for the use of the animal, or rather to enable the animal to separate for its own, those few particles which suited its taste and digestion, what more artificial or more commodious instrument of selection could have been given to it than this natural filter ? It has been observed, also, (what must enable the bird to choose and distinguish with greater acuteness, as well, probably, as what greatly increases its luxury,) that the bills of this species are furnished with large nerves, that they are covered with a skin, and that the nerves run down to the very extremity. In the curlew, woodcock, and snipe, there are *three pairs* of nerves, equal almost to the optic nerve in thickness, which pass first along the roof of the mouth, and then along the upper chap down to the point of the bill, long as the bill is.[37]

But to return to the train of our observations. The similitude between the bills of birds and the mouths of quadrupeds, is exactly such as, for the sake of the argument, might be wished for. It is near enough, to show the continuation of the same plan : it is remote enough, to exclude the supposition of the difference being produced by action or use. A more prominent contour, or a wider gap, might be resolved into the effect of continued efforts, on the part of the species, to thrust out the mouth or open it to the stretch. But by what course of action, or exercise, or endeavor, shall we get rid of the lips, the gums, the teeth, and acquire, in the place of them, pincers of horn ? By what habit shall we so completely change, not only the shape of the part, but the substance of which it is composed ? The truth is, if we had seen no other

[37] These are branches of the fifth nerve of the head, which alone, of all the nine nerves of the brain, bestows sensibility on the organ of *touch*.—ENG. ED.

than the mouths of quadrupeds, we should have thought no other could have been formed: little could we have supposed that all the purposes of a mouth, furnished with lips, and armed with teeth, could be answered by an instrument which had none of these; could be supplied, and that with many additional advantages, by the hardness, and sharpness, and figure of the bills of birds. Every thing about the animal *mouth* is mechanical. The teeth of fish have their points turned backward, like the teeth of a wool or cotton card. The teeth of lobsters work one against another, like the sides of a pair of shears. In many insects, the mouth is converted into a pump or sucker, fitted at the end sometimes with a wimble, sometimes with a forceps; by which double provision, viz., of the tube and the penetrating form of the point, the insect first bores through the integuments of its prey, and then extracts the juices. And what is most extraordinary of all, one sort of mouth, as the occasion requires, shall be changed into another sort. The caterpillar could not live without teeth; in several species, the butterfly formed from it could not use them. The old teeth, therefore, are cast off with the exuviæ of the grub; a new and totally different apparatus assumes their place in the fly. Amid these novelties of form, we sometimes forget that it is all the while the animal's *mouth*; that, whether it be lips, or teeth, or bill, or beak, or shears, or pump, it is the same part diversified; and it is also remarkable, that, under all the varieties of configuration with which we are acquainted, and which are very great, the organs of taste and smelling are situated near each other.

III. To the mouth, adjoins the gullet: in this part, also, comparative anatomy discovers a difference of structure adapted to the different necessities of the animal. In brutes, because the posture of their neck conduces little to the passage of the aliment, the fibres of the gullet, which act in this business, run in two close spiral lines, crossing each other: in men, these fibres run only a little obliquely from the upper end of the œsophagus to the stomach, into which, by a gentle contraction, they easily transmit the descending morsels; that is to say, for the more laborious

deglutition of animals which thrust their food *up* instead of *down*, and also through a longer passage, a proportionably more powerful apparatus of muscles is provided—more powerful, not merely by the strength of the fibres, which might be attributed to the greater exercise of their force, but in their collocation, which is a determinate circumstance, and must have been original.

IV. The gullet leads to the *intestines:* here, likewise, as before, comparing quadrupeds with man, under a general similitude, we meet with appropriate differences. The *valvulæ conniventes*, or, as they are by some called, the semilunar valves, found in the human intestine, are wanting in that of brutes. These are wrinkles or plates of the innermost coat of the guts, the effect of which, is to retard the progress of the food through the alimentary canal. It is easy to understand how much more necessary such a provision may be to the body of an animal of an erect posture, and in which, consequently, the weight of the food is added to the action of the intestine, than in that of a quadruped, in which the course of the food, from its entrance to its exit, is nearly horizontal; but it is impossible to assign any cause, except the final cause, for this distinction actually taking place. So far as depends upon the action of the part, this structure was more to be expected in a quadruped than in a man. In truth, it must in both have been formed, not by action, but in direct opposition to action and to pressure; but the opposition which would arise from pressure is greater in the upright trunk than in any other. That theory, therefore, is pointedly contradicted by the example before us. The structure is found where its generation, according to the method by which the theorist would have it generated, is the most difficult; but, observe, it is found where its effect is most useful.

The different length of the intestines in carnivorous and herbivorous animals, has been noticed on a former occasion. The shortest, I believe, is that of some birds of prey, in which the intestinal canal is little more than a straight passage from the mouth to the vent. The longest is in the deer-kind. The intestines of a Canadian

stag, four feet high, measured ninety-six feet.* The intestine of a sheep, unravelled, measured thirty times the length of the body. The intestine of a wild cat, is only three times the length of the body. Universally, where the substance upon which the animal feeds, is of slow concoction, or yields its chyle with more difficulty, there the passage is circuitous and dilatory, that time and space may be allowed for the change and the absorption which are necessary. Where the food is soon dissolved, or already half assimilated, an unnecessary or perhaps hurtful detention is avoided, by giving to it a shorter and a readier route.

V. In comparing the *bones* of different animals, we are struck, in the bones of birds, with a *propriety*, which could only proceed from the wisdom of an intelligent and designing Creator. In the bones of an animal which is to fly, the two qualities required are strength and lightness. Wherein, therefore, do the bones of birds (I speak of the cylindrical bones) differ, in these respects, from the bones of quadrupeds ? In three properties : first, their cavities are much larger, in proportion to the weight of the bone, than in those of quadrupeds ; secondly, these cavities are empty ; thirdly, the shell is of a firmer texture than is the substance of other bones. It is easy to observe these particulars even in picking the wing or leg of a chicken. Now the weight being the same, the diameter, it is evident, will be greater in a hollow bone than in a solid one, and with the diameter, as every mathematician can prove, is increased, *cæteris paribus*, the strength of the cylinder or its resistance to breaking. In a word, a bone of the *same weight*, would not have been so strong, in any other form ; and to have made it heavier, would have incommoded the animal's flight. Yet this form could not be acquired by use, or the bone become hollow or tubular by exercise. What appetency could excavate a bone ?

VI. The *lungs*, also, of birds, as compared with the lungs of quadrupeds, contain in them a provision distin-

* Mem. Acad. Paris, 1701, p. 170.

guishingly calculated for this same purpose of levitation, namely, a communication (not found in other kinds of animals) between the air-vessels of the lungs and the cavities of the body; so that, by the intromission of air from one to the other, (at the will, as it should seem, of the animal,) its body can be occasionally puffed out, and its tendency to descend in the air, or its specific gravity, made less. The bodies of birds are blown up from their lungs, (which no other animal bodies are,) and thus rendered buoyant.

VII. All birds are *oviparous*. This likewise carries on the work of gestation with as little increase as possible of the weight of the body. A gravid uterus would have been a troublesome burden to a bird in its flight. The advantage in this respect of an oviparous procreation is, that whilst the whole brood are hatched together, the eggs are excluded singly, and at considerable intervals. Ten, fifteen, or twenty young birds may be produced in one cletch or covey, yet the parent bird had never been encumbered by the load of more than one full-grown egg at one time.[38]

VIII. A principal topic of comparison between animals, is in their *instruments of motion*. These come before us under three divisions—feet, wings, and fins. I desire any man to say which of the three is best fitted for its use; or whether the same consummate art be not conspicuous in them all. The constitution of the elements, in which the motion is to be performed, is very different. The animal action must necessarily follow that constitution. The Creator, therefore, if we might so speak, had to prepare for different situations, for different difficulties; yet the purpose is accomplished not less successfully in one case than in the other. And as between *wings* and the corresponding limbs of quadrupeds, it is accomplished without deserting the general idea. The idea is modified, not deserted. Strip a wing of its feathers, and it bears no

[38] It has been elsewhere observed, that when predatory birds gorge themselves, they are sometimes unable to rise on the wing—a sufficient demonstration that the burden of an offspring would have unsuited them for flight.—ENG. ED.

obscure resemblance to the foreleg of a quadruped. The articulations at the shoulder and the cubitus are much alike; and, what is a closer circumstance, in both cases, the upper part of the limb, consists of a single bone, the lower part, of two.

But, fitted up with its furniture of feathers and quills, it becomes a wonderful instrument, more artificial than its first appearance indicates, though that be very striking: at least, the use which the bird makes of its wings, in flying, is more complicated and more curious than is generally known. One thing is certain, that if the flapping of the wings in flight were no more than the reciprocal motion of the same surface in opposite directions, either upwards and downwards, or estimated in any oblique line, the bird would lose as much by one motion as she gained by another. The skylark could never ascend by such an action as this; for, though the stroke upon the air by the underside of her wing would carry her up, the stroke from the upper-side, when she raised her wing again, would bring her down. In order, therefore, to account for the advantage which the bird derives from her wing, it is necessary to suppose that the surface of the wing, measured upon the same plane, is contracted, whilst the wing is drawn up; and let out to its full expansion, when it descends upon the air, for the purpose of moving the body by the reaction of that element. Now, the form and structure of the wing, its external convexity, the disposition, and particularly the overlapping, of its larger feathers, the action of the muscles and joints of the pinions, are all adapted to this alternate adjustment of its shape and dimensions. Such a twist, for instance, or semirotatory motion, is given to the great feathers of the wing, that they strike the air with their flat side, but rise from the stroke slantwise. The turning of the oar in rowing, whilst the rower advances his hand for a new stroke, is a similar operation to that of the feather, and takes its name from the resemblance. I believe that this faculty is not found in the great feathers of the tail. This is the place also for observing that the pinions are so set upon the body as to bring down the wings not vertically, but in a direction obliquely tending towards

the tail;—which motion, by virtue of the common resolution of forces, does two things at the same time—supports the body in the air, and carries it forward. The *steerage* of a bird, in its flight, is effected partly by the wings, but in a principal degree by the tail. And herein we meet with a circumstance not a little remarkable. Birds with long legs, have short tails; and in their flight, place their legs close to their bodies, at the same time stretching them out backwards, as far as they can. In this position, the legs extend beyond the rump, and become the rudder; supplying that steerage, which the tail could not.

From the *wings* of birds, the transition is easy to the *fins* of fish.[39] They are both, to their respective tribes, the instruments of their motion; but, in the work which they have to do, there is a considerable difference, founded in this circumstance. Fish, unlike birds, have very nearly the same specific gravity with the element in which they move. In the case of fish, therefore, there is little or no weight to bear up; what is wanted, is only an impulse sufficient to carry the body through a resisting medium, or to maintain the posture, or to support or restore the balance of the body, which is always the most unsteady where there is no weight to sink it. For these offices, the fins are as large as necessary, though much smaller than wings; their action mechanical; their position, and the muscles by which they are moved, in the highest degree convenient. The following short account of some experiments upon fish, made for the purpose of ascertaining the use of their fins, will be the best confirmation of what we assert. In most fish, besides the great fin, the tail, we find two pairs of fins upon the sides, two single fins upon the back, and one upon the belly, or rather between the

[39] In the higher division of animated nature, the vertebrata, one plan or system of bones can be traced through every variety from man to fishes; and this is more especially shown by the comparison of the arm with the anterior extremity of quadrupeds and the wing of birds, and even with the pectoral fin of the fish. The number of the bones, and the form and the application of the muscles to them, vary, but yet they are accommodated in a manner so perfect, that, on examining any individual among the varieties of the species, we should say that nothing could be better suited to its purpose.—ENG. ED.

belly and the tail. The *balancing* use of these organs is proved in this manner. Of the large-headed fish, if you cut off the pectoral fins—*i. e.*, the pair which lies close behind the gills—the head falls prone to the bottom: if the right pectoral fin, only, be cut off, the fish leans to that side; if the ventral fin on the same side be cut away, then it loses its equilibrium entirely; if the dorsal and ventral fins be cut off, the fish reels to the right and left. When the fish dies, that is, when the fins cease to play, the belly turns upwards. The use of the same parts for *motion*, is seen in the following observation upon them, when put in action. The pectoral, and more particularly the ventral fins, serve to *raise and depress* the fish; when the fish desires to have a *retrograde* motion, a stroke forward with the pectoral fin effectually produces it; if the fish desire to *turn* either way, a single blow with the tail the opposite way sends it round at once; if the tail strike both ways, the motion produced by the double lash is *progressive*, and enables the fish to dart forward with an astonishing velocity.* The result is, not only, in some cases, the most rapid, but in all cases, the most gentle, pliant, easy, animal motion, with which we are acquainted. However, when the tail is cut off, the fish loses all motion, and gives itself up to where the water impels it. The rest of the fins, therefore, so far as respects motion, seem to be merely subsidiary to this. In their mechanical use, the anal fin may be reckoned the keel; the ventral fins, out-riggers; the pectoral muscles, the oars; and if there be any similitude between these parts of a boat and a fish, observe, that it is not the resemblance of imitation, but the likeness which arises from applying similar mechanical means to the same purpose.

We have seen, that the *tail* in the fish is the great instrument of motion. Now, in cetaceous or warm-blooded fish, which are obliged to rise every two or three minutes to the surface, to take breath, the tail, unlike what it is in other fish, is horizontal; its stroke, consequently, perpendicular to the horizon, which is the right direction for

* Goldsmith, Hist. of An. Nat. Vol. vi. p. 154.

sending the fish to the top, or carrying it down to the bottom.[40]

[40] The poising and motion of fishes in the water has interested some of our greatest philosophers, as Galileo and Borelli. It is estimated that fishes make their way through a medium which resists nine hundred times more than the atmosphere. But then, as it offers a certain resistance to their progress, it resists also the motion of their tail and fins by which they have their power of progression. The breadth of the tail of fishes, compared with that of their fins, and its muscularity and power, declare what is affirmed to us upon authority—that the tail is the great instrument of their progression ; and we can see that when the trout darts away, the force of his motion lays down the fins close upon his body. But the fins direct him, as out-riggers, and the pectoral fins especially, by raising or depressing the head, give direction to the whole body under the force of the tail. The lateral fins, and particularly the pectoral fins, also sustain him in the right position in the water : without the cooperation of these with the tail, the fish would move like a boat sculled by one oar at the stern. As the digestion of fishes, as well as that of other animals, is attended with the extrication of air, and as the intestines are below the centre, the belly would be turned up but for the action of these lateral fins : as we see takes place in a dead fish. The tail and fins are the instruments of motion ; but the incessant action of the muscles which move these is a just matter of admiration. If a fish move with his head down the stream, he must move more rapidly than the water, or the water gets under the operculum of the gills, and chokes him. He lies, therefore, continually with his head to the stream. We may see a trout lying for hours stationary, whilst the stream is running past him ; and they seem to remain so for days and nights. In salmon-fishing, the fly is played upon the broken water, in the midst of the torrent, and there the fish shows himself rising from a part of the river where men could not preserve their footing, though assisted by poles, or by locking their arms together. When the salmon leaps, he makes extraordinary exertions. Just under the cataract, and against the stream, he will rush for some yards, and rise out of the spray six or eight feet ; and amidst the noise of the water, they may be heard striking against the rock with a sound like the clapping of the hands. If they find a temporary lodgement on the shelving rock, they lie quivering and preparing for another somerset, until they reach the top of the cataract. This exhibits not only the power of their muscles, assisted by the elasticity of their bones, but the force of instinct by which they are led to seek the shallow streams for depositing their eggs.

The porpoise will swim round and round a ship which is sailing at fourteen miles an hour : a thing almost as surprising as the fly circling round the horse's ear for a whole stage.

To all this may be added, that the solid which mathematicians have discovered, by refined application of the calculus, and have termed "the solid of least resistance," because it is the conformation which is less than any other affected by the resistance of any medium, resembles a fish in its form.—ENG. ED.

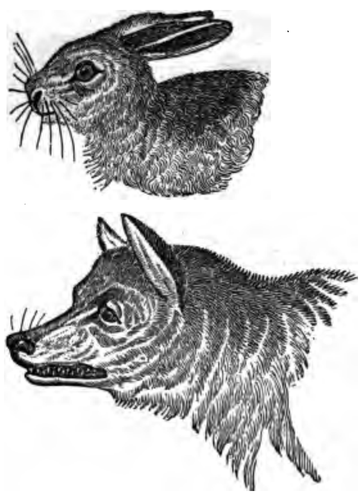
Regarding animals in their instruments of motion, we have only followed the comparison through the first great division of animals into beasts, birds, and fish. If it were our intention to pursue the consideration further, I should take in that generic distinction amongst birds, the *web-foot* of waterfowl. It is an instance which may be pointed out to a child. The utility of the web to waterfowl, the inutility to landfowl, are so obvious, that it seems impossible to notice the difference, without acknowledging the design. I am at a loss to know how those, who deny the agency of an intelligent Creator,

dispose of this example. There is nothing in the action of swimming, as carried on by a bird upon the surface of the water, that should generate a membrane between the toes. As to that membrane, it is an exercise of constant resistance. The only supposition I can think of is, that all birds have been originally waterfowl and web-footed; that sparrows, hawks, linnets, &c., which frequent the land, have, in process of time, and in the course of many generations, had this part worn away by treading upon hard ground. To such evasive assumptions, must atheism always have recourse! And after all, it confesses that the structure of the feet of birds, in their original form, was critically adapted to their original destination! The web-feet of amphibious quadrupeds, seals, otters, &c., fall under the same observation.

IX. The *five senses*, are common to most large animals; nor have we much difference to remark in their constitution, or much, however, which is referable to mechanism.

The superior sagacity of animals which hunt their prey, and which, consequently, depend for their livelihood upon their *nose*, is well known in its use; but not at all known in the organization which produces it.

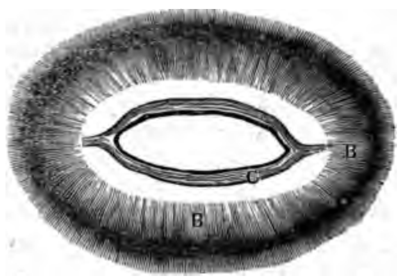
The external *ears* of beasts of prey, of lions, tigers, wolves, have their trumpet-part, or concavity, standing forward, to seize the sounds which are before them—viz., the sounds of the animals which they pursue or watch. The ears of animals of flight are turned backward, to give notice of the approach of their enemy from behind, whence he may steal upon them unseen. This is a critical distinction, and is mechanical; but it may be suggested, and, I think, not without probability, that it is the effect of continual habit.



[Heads of the hare and wolf, showing the different manner in which the ears are turned.—AM. ED.]

The *eyes* of animals which follow their prey by night, as cats, owls, &c., possess a faculty not given to those of other species, namely, of closing the pupil *entirely*.

The final cause of which, seems to be this :—It was necessary for such animals to be able to descry objects, with very small degrees of light. This capacity depended upon the superior sensibility of the retina ; that is, upon its being affected by the most feeble impulses. But that tenderness of structure, which rendered the membrane thus exquisitely sensible, rendered it also liable to be offended by the access of stronger degrees of light. The contractile range therefore of the pupil is increased in these animals, so as to enable them to close the aperture entirely, which includes the power of diminishing it in every degree ; whereby at all times such portions, and only such portions, of light are admitted, as may be received without injury to the sense.



[The figure represents the iris of a lion. B B, the straight or converging fibres ; C, the fibres which encircle the inner margin of the iris.]

There appears to be also in the figure, and in some properties of the pupil of the eye, an appropriate relation to the wants of different animals. In horses, oxen, goats, sheep, the pupil of the eye is elliptical ; the transverse axis being horizontal ; by which structure, although the eye be placed on the side of the head, the anterior elongation of the pupil catches the forward rays, or those which come from objects immediately in front of the animal's face.

CHAPTER XIII.

PECULIAR ORGANIZATIONS.

I BELIEVE that all the instances which I shall collect under this title might, consistently enough with technical language, have been placed under the head of *Comparative Anatomy*. But there appears to me an impropriety in the use which that term hath obtained ; it being, in some sort, absurd to call that a case of comparative anatomy, in which there is nothing to "compare ;" in which a conformation is found in one animal, which hath nothing properly answering to it in another. Of this kind are the examples which I have to propose in the present chapter ; and the reader will see that, though some of them be the strongest, perhaps, he will meet with under any division of our subject, they must necessarily be of an unconnected and miscellaneous nature. To dispose them, however, into some sort of order, we will notice, first, particularities of structure which belong to quadrupeds, birds, and fish, as such, or to many of the kinds included in these classes of animals ; and then, such particularities as are confined to one or two species.

I. Along each side of the neck of large *quadrupeds*, runs a stiff, robust cartilage, which butchers call the paxwax. No person can carve the upper end of a crop of beef without driving his knife against it. It is a tough, strong, tendinous substance, braced from the head to the middle of the back : its office is to assist in supporting the weight of the head. It is a mechanical provision, of which this is the undisputed use ; and it is sufficient, and not more than sufficient, for the purpose which it has to execute. The head of an ox or a horse is a heavy weight, acting at the end of a long lever, (consequently with a great purchase,) and in a direction nearly perpendicular to the joints of the supporting neck. From such a force, so advantageously applied, the bones of the neck would be in constant danger of dislocation, if they were

not fortified by this strong tape. No such organ is found in the human subject, because, from the erect position of the head, (the pressure of it acting nearly in the direction of the spine,) the junction of the vertebræ appears to be sufficiently secure without it. This cautionary expedient, therefore, is limited to quadrupeds : the care of the Creator is seen where it is wanted.[41]

II. The oil with which *birds* preen their feathers, and the organ which supplies it, is a specific provision for the winged creation. On each side of the rump of birds is observed a small nipple, yielding upon pressure a butter-like substance, which the bird extracts by pinching the pap with its bill. With this oil or ointment, thus procured, the bird dresses his coat ; and repeats the action as often as its own sensations teach it that it is in any part wanted, or as the excretion may be sufficient for the expense. The gland, the pap, the nature and quality of the execreted substance, the manner of obtaining it from its lodgement in the body, the application of it when obtained, form, collectively, an evidence of intention which it is not easy to withstand. Nothing similar to it is found in unfeathered animals. What blind *conatus* of Nature should produce it in birds ; should not produce it in beasts ?

III. The air-bladder also of a *fish*, affords a plain and direct instance, not only of contrivance, but strictly of that species of contrivance which we denominate mechanical. It is a philosophical apparatus in the body of an animal.

[41] The author is not quite correct here, inasmuch as elastic ligaments are liberally supplied in the human spine : a range of peculiar ligaments, the '*ligamenta subflava*,' run along the course of the spine, and are highly elastic. The *ligamentum nuchæ* is that ligament which runs from the prominence of the spine between the shoulders to the back of the head ; and the student, who hangs his head over his book, enjoys the advantage of this elastic support : so that it is strictly a matter comparative ; we may trace it, with increasing strength, from the ligament that sustains a man's head, to that which, like the spring of a steelyard, weighs against the immense head of the elephant.

These elastic ligaments vary with the length and motion of the neck. It would be tedious to describe their varieties in the camel, camelopard, ostrich, &c. We may be satisfied of the fact, that the elastic ligament is a structure extensively used in the animal textures, generally coming in aid of the muscles, or as a substitute for them.—Eng. Ed.

The principle of the contrivance is clear : the application of the principle is also clear. The use of the organ, to sustain, and, at will, also to elevate, the body of the fish in the water, is proved by observing, what has been tried, that, when the bladder is burst, the fish grovels at the bottom ; and also, that flounders, soles, skates, which are without the air-bladder, seldom rise in the water, and that with effort. The manner in which the purpose is attained, and the suitableness of the means to the end, are not difficult to be apprehended. The rising and sinking of a fish in water, so far as it is independent of the stroke of the fins and tail, can only be regulated by the specific gravity of the body. When the bladder, contained in the body of the fish, is contracted, which the fish probably possesses a muscular power of doing, the bulk of the fish is contracted along with it ; whereby, since the absolute weight remains the same, the specific gravity, which is the sinking force, is increased, and the fish descends : on the contrary, when in consequence of the relaxation of the muscles, the elasticity of the enclosed and now compressed air restores the dimensions of the bladder, the tendency downwards becomes proportionably less than it was before, or is turned into a contrary tendency. These are known properties of bodies immersed in a fluid. The enamelled figures, or little glass bubbles, in a jar of water, are made to rise and fall by the same artifice. A diving-machine might be made to ascend and descend, upon the like principle ; namely, by introducing into the inside of it an air-vessel, which, by its contraction, would diminish, and by its distension enlarge, the bulk of the machine itself, and thus render it specifically heavier or specifically lighter than the water which surrounds it. Suppose this to be done, and the artist to solicit a patent for his invention: the inspectors of the model, whatever they might think of the use or value of the contrivance, could by no possibility entertain a question in their minds, whether it were a contrivance or not. No reason has ever been assigned, no reason can be assigned, why the conclusion is not as certain in the fish, as it is in the machine ; why the argument is not as firm in one case as the other.

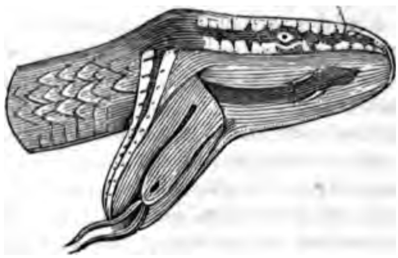
It would be very worthy of inquiry, if it were possible to discover, by what method an animal which lives constantly in water is able to supply a repository of air. The expedient, whatever it be, forms part, and perhaps the most curious part of the provision. Nothing similar to the air-bladder is found in land-animals ; and a life in the water has no natural tendency to produce a bag of air. Nothing can be further from an acquired organization than this is.[42]

These examples mark the attention of the Creator, to the three great kingdoms of his animal creation, and to their constitution, as such. The example, which stands next in point of generality, belonging to a large tribe of animals, or rather to various species of that tribe, is the poisonous tooth of serpents.

I. The *fang of a viper* is a clear and curious example of mechanical contrivance. It is a perforated tooth, loose at the root : in its quiet state, lying down flat upon the jaw, but furnished with a muscle, which, with a jerk, and by the pluck, as it were, of a string, suddenly erects it. Under the tooth, close to its root, and communicating with the perforation, lies a small bag containing the venom.

[42] The sea varies in temperature and pressure at different depths, and no doubt the texture of the fish, and especially of its integument, must conform to this variety. The swimming-bladder, is the means of adjustment, by which the fish lives at its native depths, without waste of animal exertion : such is the power of expansion of the air-bladder, when relieved from the pressure, that, when a fish is brought up from the greatest depth, it inverts and thrusts out the viscera from the mouth. We do not see, however, that naturalists have adverted to the place of this swimming-bladder. It lies close to the spine, and appears to counterbalance, in some measure at least, the air in the intestines by being thus placed above them. In the cetacea, as the whale, their buoyancy proceeds from the quantity of oil under the skin, especially of their head, and which, it has been observed, is bestowed, in order to insure their readily coming to the surface to breathe, when their natural powers are weakened. For the same reason, that they may raise their heads to the surface, their tails are horizontal. In the jelly-fish, those soft animals which float in sheltered estuaries, (the *physsophora,*) there is an air-vessel which they can fill and empty, by which means they rise or sink at pleasure. Others, (the *villela,*) raise a sail. Some of this class propel themselves by taking in water, and suddenly rejecting it.—ENG. ED.

When the fang is raised, the closing of the jaw presses its root against the bag underneath; and the force of this compression sends out the fluid with a considerable impetus through the tube in the middle of the tooth.



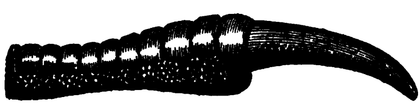
[We here represent the head of a viper, the size of life, for the purpose of showing the peculiar contrivance above mentioned; and also its fang, greatly enlarged. A hair is represented in the tube through which the poison is ejected.—AM. ED.]

What more unequivocal or effectual apparatus could be devised, for the double purpose of at once inflicting the wound and injecting the poison? Yet, though lodged in the mouth, it is so constituted, as, in its inoffensive and quiescent state, not to interfere with the animal's ordinary office of receiving its food. It has been observed also, that none of the harmless serpents, the black snake, the blindworm, &c., have these fangs, but teeth of an equal size; not movable as this is, but fixed into the jaw.

II. It being the property of several different species, the preceding example is resembled, by that which I shall next mention, which is the *bag of the opossum*. This is a mechanical contrivance, most properly so called. The simplicity of the expedient, renders the contrivance more obvious than many others, and by no means less certain.

A false skin, under the belly of the animal, forms a pouch, into which the young litter are received at their birth; where they have an easy and constant access to the teats; in which they are transported, by the dam, from place to place; where they are at liberty to run in and out; and where they find a refuge from surprise and danger. It is their cradle, their asylum, and the machine for their conveyance. Can the use of this structure be doubted of? Nor is it a mere doubling of the skin; but it is a new organ, furnished with bones and muscles of its own. Two bones are placed before the os pubis, and joined to that bone as their base. These support, and give a fixture to, the muscles which serve to open the bag. To these muscles there are antagonists, which serve, in the same manner, to shut it; and this office they perform, so exactly, that, in the living animal, the opening can scarcely be discerned, except when the sides are forcibly drawn asunder.* Is there any action, in this part of the animal, any process, arising from that action, by which these members could be formed? any account to be given of the formation, except design?

III. As a particularity, yet appertaining to more species than one, and also as strictly mechanical, we may notice a circumstance in the structure of the *claws* of certain birds. The middle claw of the heron and cormorant is toothed and notched like a saw. These birds



[The above cut represents the claw of a heron.—AM. ED.]

are great fishers, and these notches assist them in holding their slippery prey. The use is evident; but the structure such, as cannot at all be accounted for by the effort of the animal, or the exercise of the part. Some

*Goldsmith, Nat. Hist. vol. iv. p. 244.

other fishing birds have these notches in their *bills*; and for the same purpose. The gannet, or Soland goose, has the side of its bill irregularly jagged, that it may hold its prey the faster.

Nor can the structure in this, more than in the former case, arise from the manner of employing the part. The smooth surfaces, and soft flesh of fish, were less likely to notch the bills of birds, than the hard bodies upon which many other species feed.

We now come to particularities strictly so called, as being limited to a single species of animal. Of these, I shall take one from a quadruped, and one from a bird.

1. The *stomach of the camel* is well known to retain large quantities of water, and to retain it unchanged for a considerable length of time. This property qualifies it for living in the desert. Let us see, therefore, what is the internal organization, upon which a faculty so rare and so beneficial depends. A number of distinct sacs or bags (in a dromedary, thirty of these have been counted) are observed to lie between the membranes of the second stomach, and to open into the stomach, near the top, by small square apertures. Through these orifices, after the stomach is full, the annexed bags are filled from it: and the water so deposited is, in the first place, not liable to pass into the intestines; in the second place, is kept separate from the solid aliment; and, in the third place, is

out of the reach of the digestive action of the stomach, or of mixture with the gastric juice. It appears probable, or rather certain, that the animal, by the conformation of its muscles, possesses the power of squeezing back this water from the adjacent bags into the stomach, whenever thirst excites it to put this power in action.

[THE STOMACH OF THE HORSE.

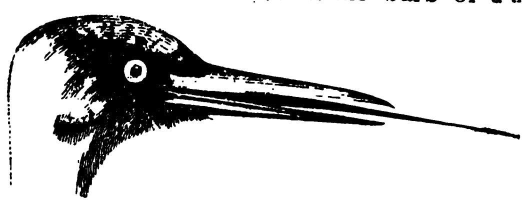
When we think of the adaptations of animal structure to the different conditions of living creatures, the camel, the ship of the desert, immediately occurs ; and no doubt it is highly interesting to observe how this animal is adapted to the sandy waste, in its eye, its nostril, its foot, the cells of its stomach, and its capacity of endurance. But it is, perhaps, more to our purpose, to look to our domestic animals ; and the most of all deserving attention, is the horse.

Of all creatures, the horse has the smallest stomach, relatively to its size. Had he the quadruple ruminating stomach of the ox, he would not have been at all times ready for exertion : the traveller could not have baited his steed and resumed his journey. The stomach of the horse is not so capacious, even when distended, as to impede his wind and speed ; and the food is passing onward with a greater degree of regularity than in any other animal. A proof of this is, that the horse has no gall-bladder. Most people understand that bile is necessary to digestion ; and the gall-bladder is a receptacle for that bile. Where the digestive process is performed in a large stomach, and the food descends in larger quantities, and at long intervals, the gall-bladder is necessary ; and there is that sympathy between the stomach and gall-bladder, that they are filled and emptied at the same time. The absence of the gall-bladder in the horse, therefore, implies the almost continual process of digestion ; which again results from the smallness of the stomach.

Another peculiarity in the horse, is, the supply of fluid. When the camel drinks, the water is deposited in cells connected with the stomach ; but if a horse drinks a pail

of water, in eight minutes none of that water is in his stomach; it is rapidly passed off into the large intestine and the cæcum. We cannot resist the conviction that this variation in the condition of the digestive organs of the horse, is in correspondence with his whole form and properties, which are for sudden and powerful, as well as long-continued exertion.—SIR CHARLES BELL.]

II. The *tongue of the woodpecker* is one of those singularities, which nature presents us with, when a singular purpose is to be answered. It is a particular instrument for a particular use; and what, except design, ever produces such? The woodpecker lives chiefly upon insects lodged in the bodies of decayed or decaying trees. For the purpose of boring into the wood, it is furnished with a bill, straight, hard, angular, and sharp. When, by means of this piercer, it has reached the cells of the insects, then comes the office of its tongue: which tongue is, first, of such a length that the bird can dart it out three or four inches from the bill,—in this respect differing greatly from every other species of bird; in the second place, it is tipped with a stiff, sharp, bony thorn; and, in the third place, (which appears to me the most remarkable property of all,) this tip is dentated on both sides like the beard of an arrow or the barb of a hook.



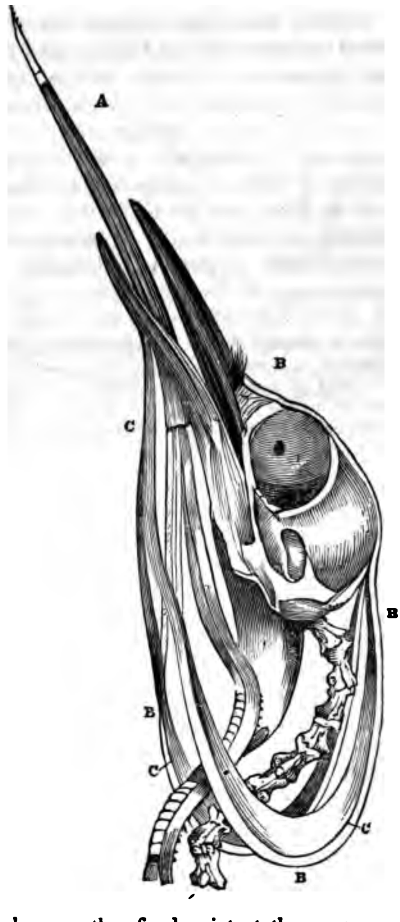
[We here represent the head of a woodpecker with its *tongue* protruded, and also the tongue, separate, the size of *life*.—AM. ED.]

The description of the part declares its uses. The bird, having exposed the retreats of the insects by the assistance of its bill, with a motion inconceivably quick, launches out at them this long tongue; transfixes them upon the barbed needle at the end of it; and thus draws its prey within its mouth. If this be not mechanism, what is? Should it be said, that, by continual endeavors to shoot out the tongue to the stretch, the woodpecker species may by degrees have lengthened the organ itself, beyond that of other birds, what account can be given of its form; of its tip? how, in particular, did it get its barbs, its dentation? These barbs, in my opinion, wherever they occur, are decisive proofs of mechanical contrivance.[43]

[43] What could have tempted Buffon to express his pity for this bird as abject and degraded, it is not easy to conceive : nor why it should be described as leading an insipid life, because continually employed in boring and hammering the old stump of a tree. A late naturalist describes the woodpecker as enjoying the sweet hours of the morning, on the highest branch of the tallest tree, fluttering and playing with his mate and companions. No doubt his diligence, perseverance, and energy in plying his beak is very extraordinary. But, besides the wedge-like strength of the beak, and the power of the neck to strike with it, there is something remarkable in its sensibility. That nerve, the fifth pair, on which we have shown that all the sensibility of the head depends, transmits a large branch along the inside of the mandibles : and, as this nerve approaches the extremity, it perforates the bone by innumerable small canals, so as to be given to the horny covering of the beak, which is thus possessed of a sensibility to feel in the crevices of the wood, and under the bark ; and the woodpecker is enabled, by this means, to direct the tongue, which our author correctly describes as moving with extraordinary celerity, and with a point like a barbed arrow.

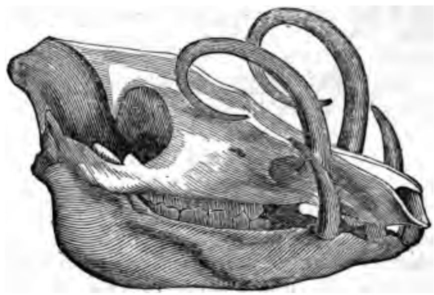
We have represented the dissection of the head of this bird more accurately in its anatomy than is to be found in books. We offer it because it exhibits a very curious piece of mechanism, adjusted to the tongue, to enable the animal to thrust it out far, and with unusual rapidity. A, is the barbed tongue; B B B B, two slender elastic ligamentous cartilages, of very peculiar structure and use. On one extremity, they are attached to the bone which supports the upper mandible ; from this we trace them over the skull, down upon the sides of the neck ; and, with a large sweep, turning under the lower mandible, and so continued into the tongue, and not terminating until they reach the horny point. C C C, a long muscle which follows these ligamentous cartilages upon their concave side, arising from the bone of the lower mandible, and so sweeping round with the cartilages and over

III. I shall add one more example, for the sake of its novelty. It is always an agreeable discovery, when,



the skull, to have another fixed point at the upper mandible: these protrude the tongue. Two muscles are seen to arise from the sides of the larynx, which are the opponents of the last, and retract the tongue. Leaving the other parts of the anatomy, we beg the reader's attention *to the action* of the muscle C C C, which presents one of those curious

having remarked in an animal an extraordinary structure, we come at length to find out an unexpected use for it. The following narrative furnishes an instance of this kind. The babyroussa, or Indian hog, a species of wild boar, found in the East Indies, has two *bent* teeth, more than half a yard long, growing upwards, and (which is the



instances observed in comparative anatomy, of a mechanism adapted to a particular purpose. The tongue is not only thrust out far by this apparatus, but is shot with great rapidity, in correspondence with its barbed point. This effect is produced by the two extremities of the muscle being fixed points, and the fibres of the muscle itself running on the concave side of the cartilaginous bow, so as to form a smaller circle. We require no mathematical demonstration,to prove that the tongue must be thrust out,to a greater distance than the measure of contraction of the muscle. Let us tie the line of the fishing-rod to its slender top, and pull upon it at the butt: the motion of the top will be very extensive, even when only an inch of the line is drawn through the rings. This is a pretty accurate representation of what takes place by the contraction of this protruding muscle. We have noticed, that the upper end of this arch is fixed, the whole motion must therefore be given to the loose extremity in the tongue ; and we cannot but observe, that this peculiar arch and muscular ring are adapted for the rapid protrusion of the tongue ; whilst its retraction is produced by a common muscle, that is, a muscle running in a straight course.

Another curious part of this apparatus is, that a very large gland, which pours out a glutinous matter, is embraced and compressed by the action of the circular muscle. This viscid secretion, bedewing the tongue, furnishes an additional means for the bird to pick up insects, such as ants, without the necessity of sticking each with its arrow. Nothing can be more mechanical, or more happily adapted to its purpose, than the whole of this structure, and consequently nothing better suited to strengthen the argument in the text. Indeed it is not inferior to the means employed for giving rapidity of motion *to the membrana nictitans* of the eye of the bird.—ENG. ED.

singularity) from the upper jaw. These instruments are not wanted for offence; that service being provided for by two tusks issuing from the under jaw, and resembling those of the common boar: nor does the animal use them for defence. They might seem, therefore, to be both a superfluity and an encumbrance. But observe the event;—the animal sleeps standing; and in order to support its head, hooks its upper tusks upon the branches of trees.[44] *

CHAPTER XIV.

PROSPECTIVE CONTRIVANCES.

I CAN hardly imagine to myself a more distinguishing mark, and, consequently, a more certain proof of design, than *preparation*,—*i. e.*, the providing of things beforehand, which are not to be used until a considerable time afterwards: for this implies a contemplation of the future, which belongs only to intelligence.

Of these *prospective* contrivances, the bodies of animals furnish various examples.

I. The human teeth afford an instance, not only of prospective contrivance, but of the completion of the

[44] This notion of the babyroussa sleeping on its feet, and hanging by its teeth the while, is a mere fancy. It has arisen from the difficulty of accounting for the teeth, which rise out from the mouth, and turn up before the eyes. The better opinion is, that they guard the eyes in rushing through the thick underwood.—ENG. ED.

* [Barrow, in his 'Voyage to Cochin China,' speaking of this strange conjecture, which we believe originated with Buffon, and received additional publicity through Goldsmith, says, "The same species, or one so like it that the difference is not distinguishable by any description or drawing that I have seen, is common among the rocks in the deserts of Southern Africa, where, within the distance of a hundred miles, there is neither tree nor shrub, except a few stunted heaths or shrivelled everlastings, thinly scattered over the barren surface. In such situations, where I have hunted and taken them, it would certainly be no easy matter for the babyroussa to find a peg to hang its head upon." *AM. ED.*]

contrivance being designedly suspended. They are formed within the gums, and there they stop: the fact being, that their further advance to maturity would not only be useless to the new-born animal, but extremely in its way; as it is evident, that the art of *sucking*, by which it is for some time to be nourished, will be performed with more ease, both to the nurse and to the infant, whilst the inside of the mouth and edges of the gums are smooth and soft, than if set with hard-pointed bones. By the time they are wanted, the teeth are ready. They have been lodged within the gums for some months past; but detained, as it were, in their sockets, so long as their further protrusion would interfere with the office to which the mouth is destined. Nature, namely, that intelligence which was employed in creation, looked beyond the first year of the infant's life; yet, whilst she was providing for functions which were after that term to become necessary, was careful not to incommode those which preceded them. What renders it more probable that this is the effect of design, is, that the teeth are imperfect, whilst all other parts of the mouth are perfect. The lips are perfect, the tongue is perfect; the cheeks, the jaws, the palate, the pharynx, the larynx, are all perfect; the teeth alone are not so. This is the fact with respect to the human mouth; the fact also is, that the parts above enumerated are called into use from the beginning; whereas the teeth would be only so many obstacles and annoyances, if they were there. When a contrary order is necessary, a contrary order prevails. In the worm of the beetle, as hatched from the egg, the teeth are the first things which arrive at perfection. The insect begins to gnaw, as soon as it escapes from the shell, though its other parts be only gradually advancing to their maturity.

What has been observed of the teeth, is true of the *horns* of animals; and for the same reason. The horn of a calf or a lamb does not bud, or at least does not sprout to any considerable length, until the animal be capable of browsing upon its pasture; because such a substance upon the forehead of the young animal, would very

much incommode the teat of the dam, in the office of giving suck.

But in the case of the *teeth*—of the human teeth, at least, the prospective contrivance looks still further. A succession of crops is provided, and provided from the beginning; a second tier being originally formed beneath the first, which do not come into use till several years afterwards. And this double or suppletory provision, meets a difficulty in the mechanism of the mouth, which would have appeared almost insurmountable. The expansion of the jaw, (the consequence of the proportionable growth of the animal, and of its skull,) necessarily separates the teeth of the first set, however compactly disposed, to a distance from one another, which would be very inconvenient. In due time, therefore, *i. e.*, when the jaw has attained a great part of its dimensions, a new set of teeth springs up, (loosening and pushing out the old ones before them,) more exactly fitted to the space which they are to occupy, and rising, also, in such close ranks, as to allow for any extension of line which the subsequent enlargement of the head may occasion.[45]

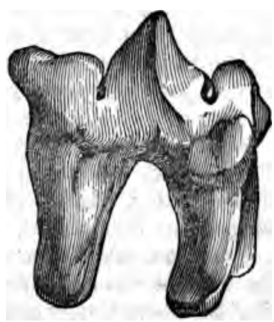
[OF THE TEETH OF ANIMALS—THEIR MECHANICAL PROVISIONS.

The teeth form a subject of much higher interest than will at first be readily imagined. There is no part of an animal body where 'contrivance' is more distinctly demonstrated, or in which a resemblance is more obvious between the mechanism of engines, and the provisions in the animal mechanism. Suppose an instrument were to

[45] The second or permanent set of teeth, does not push out the deciduous or milk teeth. The process is not mechanical. Whilst yet a tender membrane is around the second tooth, those of the first set are suffering absorption at their fangs. Another circumstance, which shows the provision not to be mechanical, is, the wasting of the old alveolar process, and the growth of the new; the new alveolar process, or socket of the permanent tooth, is forming at the time that the portion of the jaw which held the first tooth firm is yielding by absorption. —ENG. ED.

be ingeniously contrived to cut like an adze, or to divide like a pair of shears, or to grind like a millstone, or to hold like a mousetrap,* or to tear,—what, after a period of working, would be the condition of these machines? Would not the edge be blunted, the sharp points become rounded, the grinding surfaces smoothed? and would not the teeth of the machine be driven deep into the sockets, and so render it wholly useless? But nothing of this kind takes place in the teeth of animals. They are perfect for their purpose, and, if duly exercised, last the natural term of life, however the period of natural decay may vary in different animals.

To commence with the manner in which the teeth resist pressure into the jaw. If we look to the teeth of the lion, we find their roots conical and socketed, as if a nail were driven in; and so it is in the remarkably strong teeth of the hyæna.



The figure represents the back tooth of the Tiger's jaw, which closes like the blades of scissors.

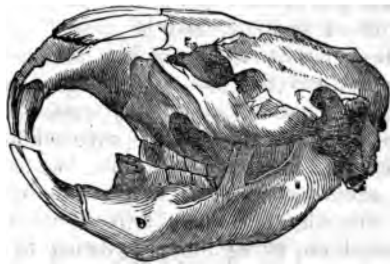
Now these animals have powerful muscles, closing the jaws with a force to break the strongest bone. How is it, then, that the teeth are never pressed deeper into the jaw. For undoubtedly this would be the effect in an

* As in the gullet of fishes.

engine so constructed by man's ingenuity. The reason is, that there is a living property in the teeth and jaw, by which the former are made to protrude from their sockets, in proportion to the pressure to which their crowns, that is, their exposed parts, are subjected. It is very remarkable, that the teeth, during their period of growth, notwithstanding they are exposed to the pressure of mastication, will ascend or protrude more and more out of the jaw; and, when fully grown, they will remain stationary and on a level, if subjected to the natural pressure of mastication; but without this, they will rise too high, project, and at last fall out. It is on this principle, that if we lose teeth in one jaw, we lose them in both: and there are no means of preventing the loss of these, but by such mechanical substitutes as shall restore them to their due exercise. And yet Nature modifies the law with perfect ease, and, as it were, at will. Let us take an example:

The front teeth of the horse are called "nippers;" they meet, and crop the herbage. As the horse is a vegetable feeder, he must grind with his back teeth; and during this act, the front teeth must participate in the grinding motion. We shall presently see how they are protected against this attrition. But in the ruminant animals, those which chew the cud, there is a necessity for a more thorough grinding of the food, whilst at the same time the front teeth must preserve their edge. For this purpose, the teeth are wanting in the fore part of the upper jaw, and there is only a cushion, which embraces and holds the grass against the edge of the lower teeth, so that it is cut as with a sickle, by a smart twitching motion of the head. Thus the front teeth undergo no attrition. Now, although there be no teeth in the upper jaw, those below do not rise or become loose, as they certainly would, in man, or in any other animal, not of the class of ruminants. Two objects are here attained:—first, that the cutting teeth are preserved sharp; and, in the second place, these teeth differ in their condition from ours, since they do not rise in consequence of wanting opponents.

In the class of rodentia or gnawers, the front teeth *must cut* with a sharp edge. We know how this is con-



The figure represents the skull of the Beaver, to show the nature of their cutting teeth.

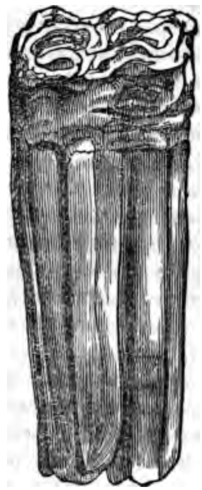
trived in the tool of the carpenter; and we know also that he must, from time to time, apply his chisel to the grindstone. The front teeth of the beaver, the porcupine, and the rat, are sharp, and yet not blunted by use; the bone of the tooth is the densest possible, consistent with the material: but were the whole tooth of the same material, it would be ground down uniformly, and the original form of the instrument would be lost. Accordingly, a different substance, the enamel, which yields more slowly to attrition than the bone of the tooth, is, as it were, let in on the anterior surface of the tooth. The consequence is, that the enamel stands up sharp and exposed, so as to protect the bone of the tooth, and to give the surface which is worn down a certain shape, viz., that original shape suited to cut like an adze. The attrition and the arrangement of the material of the tooth so far correspond, that the cutting form is preserved, however much the surface may be worn down.

Now a tooth cannot grow; and, as we have seen that it is wasted by friction, how is the cutting edge to retain its place? When the steel plate of the carpenter's plane is forced in, by repeated taps with his hammer, he projects the sharp edge, and when it is elevated above the plane, in a just degree, he fixes it there by a smart blow on the wedge: but the cutting edge of the chisel-like in-
··ors of the rodentia is still more finely adjusted.

In the first place, the tooth is very long, extending the whole length of the jaw, and it is of a curve not easily described, not partaking of any section of a cone; still it is so adapted that the cutting edge meets its opponent tooth, and although incessantly wasted, it is accommodated to the growing jaw. We have said, that a tooth does not grow. It does not grow, like a bone; but sometimes additions are given to it, at the root; such is the case in this class of animals: the tooth of the gnawer is thus pushed on, along the jaw, owing to the growth taking place at its root, and in its proper curve: so that the cutting edge is protruded, in proportion as it is wasted in the process of attrition and sharpening. This is a mode of growth, which takes place in no other animal's incisor tooth.

Let us now observe, how the grinding surface of the tooth of an herbivorous animal is composed. It must be rough or irregular, so as to catch the grain. A smooth millstone, for example, would not bruise the grain into meal. The burr-stone, accordingly, is sought for the nether millstone. This stone contains small portions of feldspar, imbedded in a softer material: and thus, however the surface may be ground down, the harder material, by yielding less easily to friction than the softer, projects above the general level, and preserves a roughness of the surface even whilst it is yielding. It is exactly so with the tooth of a graminivorous animal. It is composed of alternate layers of the hardest bone, or rather of ivory, and a denser material still, the enamel. The consequence of this inequality in the composition, is, that, notwithstanding the surface of the tooth is worn down, the roughness is preserved.

There is something curious, too, in this irregularity, showing that it is as far as possible from accident. The lines of enamel which stand up, differ in their arrangement according to the motion to be given to the jaw. In the horse and cow, these ridges run parallel with the jaw, and consequently lie across the direction of the motion of chewing, which is from side to side. In the rodentia, on the other hand, the line of the enamel of the grinding teeth



The figure represents the molar tooth of the horse, and exhibits the roughness of its upper surface, and the depth of the body of the tooth in the jaw, commensurate to the pressure it bears.

runs transversely to the jaw; and in mastication, the jaw is drawn backwards and forwards, not laterally. This original composition of a grinding tooth, is, therefore, superior to the best millstone. The roughness, which is so like a thing accidental, is found to proceed from an arrangement in accordance with the motion of mastication. It might, in like manner, be easily demonstrated, that there exists a similar accordance with the form of the jaw and with its articulation; but the instances already given of adaptation may suffice.

Before leaving the subject of the provisions against the wasting of the teeth by friction, there are one or two circumstances of a very interesting nature to be noticed. The elephant is a graminivorous animal, and requires to grind its food very thoroughly. What, then, must be the provision in the grinding tooth of this animal, to withstand the

power of its jaws? We find the teeth, in fact, formed of three substances, and, we may say, of a structure superior to the teeth of the lesser graminivorous animals, of course admirably suited to resist the action of chewing. But there is a circumstance peculiar here. Although the matter of the tooth, once formed, does not change, an alteration in the position of the tooth in the jaw may produce a similar result. When the great grinding tooth of the elephant appears first above the jaw, the anterior corner only projects: but as that becomes worn down, the tooth, by revolving on its centre, presents, in slow, but regular succession, more and more of the surface, guarded with new plates of enamel, until it is at last worn to the roots. Here, then, we have a new and extraordinary provision against attrition, in the teeth of an animal which lives to a great age. The structure of the tooth itself has a very large proportion of enamel, in dense and regular ridges: but as if the material of the teeth could be brought to no greater perfection to withstand the chewing, it is "contrived," for we have license for such language in our author, that the tooth itself shall undergo a revolution, not being simply elevated from the jaw, but turning on an axis.

There are other modes, in which Nature counteracts the wear and tear of the engine; and the provision which we have now to mention, supplies not only a substitution of more perfect teeth for those that are injured, but teeth of a size as well as form suited to the growing jaw. In the crocodile, for example, the teeth are conical and sharp; but if not worn, they must be torn away, and there is a necessity for a succession. It is thus provided: under the exposed tooth, there is another one lodged, of the same shape; and under that, a second and a third. Each tooth, as it is deeper in the jaw, is larger in its base, and longer and stronger. So it happens, that when a tooth is torn off, it is only the uncapping of a sharper and a stronger tooth.

The same end is attained, differently, in other creatures. In the rays, such as the skate, and in the shark, the succession of the teeth is still more curiously managed.

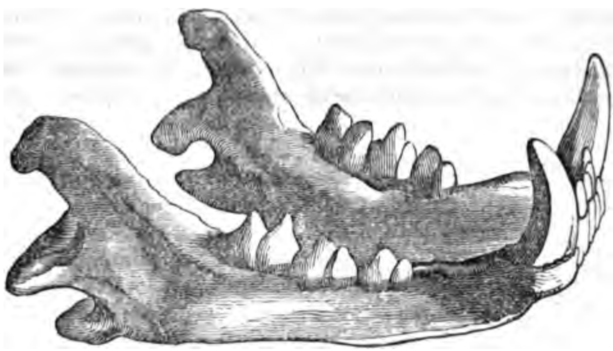
The jaws resemble a part of a cylinder, studded with many rows of teeth. The teeth of the outermost row, being in use, are liable to be torn off or worn down; when this occurs, their places are supplied by a revolving of the solid base on which the teeth are studded, and the posterior ranges advance in succession. Here, then, we not only find sharp and cutting teeth, like those of a saw: but, corresponding with the boldness and voracity of the animal, we see a provision for their rapid renewal.

It is interesting to see, how the same class of parts may be modified, and yet retain their original destination of supplying the stomach with food, and preparing it for digestion. What teeth could we suppose suited for the whale? Now the largest species of whale feed upon a small molluscous animal, which abounds in the northern ocean. The teeth are here, we may say, converted into a substance like horn; with which we are familiar under the name of whalebone. They consist of plates of this whalebone attached to the upper jaw, and placed in rows on the outer margins. Their loose edges terminate in a fringe, as if the plates were split and teased into shreds; and this is undoubtedly for the purpose of retaining the small fry, while the water is drained through their interstices.

In this curious apparatus, there is, of course, no necessity for great strength in the jaw, nor for very powerful muscles to move them. The head of the animal needs not, therefore, be denser in its texture, nor less buoyant than the rest of the body. What would be required, if any of the species had jaws or teeth at all corresponding with their size? They could not lie horizontally; their head would, from its weight, be depressed, and their tail elevated towards the surface of the water. We need not, however, strain our ingenuity to sav what would be required; for Nature has demonstr this defect is to be remedied. The spermac which has teeth, has also cavities in its head, a material much lighter than water, the sperm this counterpoises the weight of the teeth and restores the equilibrium of this cetaceous anir

We have, perhaps, said enough on this part of our subject. But, as we have seen how strangely the teeth vary, to be adapted to their office of cutting and grinding, we may observe that they are sometimes adapted to different purposes.

The common classification of the teeth is into incisors, canine, and molar or grinding teeth. Let us take our example from the canine teeth. In man, they are of great length and strength: their fangs project deep into the upper jaw; they are called the eye-teeth; and they tend to sustain and give strength to the range of the incisors. In the carnivorous animal, they are called "laniarii;" they are for tearing and holding; for which purpose, there is a correspondence between them and the hooked claws.



The figure of the lower jaw of the Tiger.

The tusks of the elephant are of this class; and between these, the tender trunk is protected. In the boar, the canine teeth project, and become powerful instruments, not for biting, or holding, or tearing, but for rending or rather cutting: that is, the whole force of the animal in its rush is directed to give effect to the tusk. So little are the tusks calculated for biting, that the tusk of the lower jaw closes in upon that of the upper jaw, so as to support its base, and to give it strength, commensurate to the power and impetus of the animal. But we must not

suppose that the tusks are solely for the purpose of offence. The strength and the power of the neck of the boar is mainly for the purpose of ploughing up the earth, and rooting up herbs, by means of its tusks.

In some animals, as the babyroussa, this tooth rises and twists so as to make it at first sight appear useless. Certainly, the tusk is neither for holding, tearing, nor masticating; yet it is not useless. This animal escapes from his enemies by the facility with which he rushes through the brushwood; and these teeth are curiously calculated to bear aside the branches and to protect the eyes.

In other animals, as the walrus, the canine teeth of the upper jaw become tusks, but project in an opposite direction to those of the elephant. They enable the animal to raise itself out of the water, by holding on upon the rock or iceberg, as the parrot steadies himself by the bill.

THE SUBJECT PURSUED WITH REFERENCE TO THE FORMATION AND GROWTH OF TEETH.

Seeing how admirably these instruments have been adapted to their several uses, the reader must be curious to know how they are produced—how they are manufactured, with so fine a "prospective contrivance." Three different substances are exposed on making the section of a tooth; viz. ivory, or the bone of the tooth; the enamel, which is very hard, and breaks with a vitreous fracture; and a substance, differing in some respects from both, and which English anatomists have called crusta petrosa, and Cuvier, cement. These three substances are not formed in every tooth. Some teeth, consist entirely of the bone or ivory, as those of the porpoise and bottle-nosed whale. In man, and in the carnivorous animals, the bone is covered with enamel, and in the graminivorous animals and ruminant animals, all three substances are found.

In the chapter on bone, it has been shown, that its texture must be loose, to admit blood-vessels; for bone is nourished and undergoes changes, through the influence of the circulating blood in it. But the almost stony den-

sity of the teeth does not admit of circulation within them; yet they possess life, and through that principle are in union with the gum and jaw. A dead tooth, however pure and perfect, when thrust into the socket of the jaw, remains there no longer than would a peg of wood or of metal. It causes inflammation and pain, and is thrown out.

It would be a difficult question, for those who consider life to be the result of organization, to solve, how a principle of life should exist, for a term of years, giving rise to a sympathy and union with the jaw, in a part like the bone of a tooth, which has neither what they call organization, nor any circulation of blood in it. Here we have one of those inscrutable qualities of life, which makes physiology a science distinct from all others; and it is an example of there being adaptations far more admirable than merely mechanical appliances.

But we were about to show how the different portions of a tooth are formed. In the jaw of the young animal, a sac is discovered, which contains the rudiments of the tooth. On opening the sac, we think we see the tooth, but it is only a body of the form of the crown of the tooth, and is soft to the touch. This is called the *pulp* of the tooth; although pale at first, at a stated period it becomes full of blood, and then the bone of the tooth begins to be formed; and now, on touching it, we can lift from it a delicate shell, which is at once of the form of the pulp, and of the perfect tooth. The process thus begun, is completed by the secretion of successive strata from the surface of the pulp, until the bone of the tooth, which was at first a mere scale, becomes a dense body, with a small cavity and tube leading to it; and the pulp, which was of the size and shape of the tooth, shrinks to a mere shred, containing a nerve and vessels.

Thus, the original use of the pulp is changed: but it remains, serving an important purpose; for, by sustaining a sensible nerve within the tooth, it extends a degree of protection to it. The teeth are sensible to what we masticate; they are sensible to the smallest particle of sand, and so are they to the degrees of heat. This sensibility *is necessary* to their protection, and to the continuance

of their vitality, yet the sensibility is not in the substance of the tooth, but in the nerve within; and the density of texture of the tooth becomes a medium through which both mechanical vibration and heat are readily communicated to the nerve.

We have seen how the bone of the tooth is secreted by the pulp. The enamel is formed differently. The sac, which covers the whole pulp and rudiments of the tooth, has a fine organization, as displayed by the art of the anatomist, and its inner surface throws out a fluid, which, falling on the surface of the bone of the tooth, (already formed by the pulp,) there concretes, or undergoes a species of crystallization, and hardens into enamel.

The difference between the bone and enamel of a tooth, that is, between what is formed by the pulp and by the sac, is shown by a very simple process. When a tooth is immersed in diluted nitric, or in muriatic, acid, the enamel is dissolved with effervescence, and is completely carried away; but when the earth of the bony part is dissolved, it leaves behind it a cartilaginous matter, which constituted a part of the bone of the tooth. In its chemical composition, the bone of the tooth resembles the bone of the skeleton, though not strictly and anatomically, as it wants the vascularity of true bone; it is, therefore, with more propriety, called ivory.

We have still to explain, how the compound teeth of the vegetable feeders are formed. Now, if we comprehend the means employed in the simple tooth, we shall have little difficulty in understanding this. The pulp is divided, and consists of parallel layers, joined below, but free above, and with considerable interstices. These divisions or processes of the pulp, secrete the ivory upon their surfaces, by which, of course, plates of this dense material are formed on each side of the soft processes or tongues of the pulp. There will, therefore, be double the number of plates of bone that there are processes of the pulp.

Each plate of bone must be covered or invested with enamel. This is effected by folds or projecting processes of the capsule or sac, which, hanging from above, inter-

vene between the plates of bone, and there perform their peculiar secretion, depositing the enamel. But it would appear that these processes, becoming at length tightly embraced by the plates of enamel which they have themselves secreted, throw out a less perfect material, as it were; this is called the *crusta petrosa* or cement. When the tooth thus formed rises above the gum, and when attrition wears down a part of it, the interstices caused by the wasted processes of the septa of the sac are exposed, and the food is crammed down into these crevices, and then, on making a section of the tooth, we may discover four substances, ivory, enamel, crusta petrosa, and foreign matter, in alternate layers.

Now, contemplating the slow formation of the teeth, whilst yet deep in the jaw; their curious mode of growth, adapted to the form of the jaw; the articulation of the jaw with the head; the position and powers of the muscles that are to move the jaw, with the means to be employed by the animal in gathering, masticating, and digesting its food,—we can desire no more absolute proof of prospective contrivance and design. Were we to seek further, we have only to compare these mechanical appliances, with the instincts and propensities of the animals.

There is but one thing, more worthy of attention in the teeth, than their mechanism; we mean their vital properties. Is it not a wonderful thing to see the jaw of the infant with a ridge upon its gums, harmless to the nipple; and then, at the time when the powers of digestion vary, and become suited for stronger food, to find sharp teeth arise, a range of them having been provided, which, when fully developed, are in exact accordance with the size and form of the jaw of the child? Can any one tell us how these teeth should waste at an appointed time, to give place to others, of stronger form and of larger dimensions, conforming to the adult jaw-bone? The phosphate, carbonate, and fluate of lime, do not differ in these milk teeth, or deciduous teeth, and in the adult teeth; yet, by a secret process of decay, the first fall out in the period of childhood, and the second last a long lifetime.—SIR CHARLES BELL.]

II. It is not very easy to conceive a more evidently prospective contrivance than that which, in all viviparous animals, is found in the *milk* of the female parent. At the moment the young animal enters the world, there is its maintenance, ready for it. The particulars to be remarked in this economy, are neither few nor slight. We have, first, the nutritious quality of the fluid, unlike, in this respect, every other excretion of the body; and in which Nature hitherto remains unimitated, neither cookery nor chemistry having been able to make milk out of grass: we have, secondly, the organ for its reception and retention: we have, thirdly, the excretory duct annexed to that organ: and we have, lastly, the determination of the milk to the breast, at the particular juncture when it is about to be wanted. We have all these properties in the subject before us, and they are all indications of design. The last circumstance, is the strongest of any. If I had been to guess beforehand, I should have conjectured, that at the time when there was an extraordinary demand for nourishment, in one part of the system, there would be the least likelihood of a redundancy, to supply another part. The advanced pregnancy of the female, has no intelligible tendency to fill the breast with milk. The lacteal system is a constant wonder; and it adds to other causes of our admiration, that the number of the teats or paps in each species is found to bear a proportion to the number of the young. In the sow, the bitch, the rabbit, the cat, the rat, which have numerous litters, the paps are numerous, and are disposed along the whole length of the belly: in the cow and mare, they are few. The most simple account of this, is to refer it to a designing Creator.[46]

[46] The only parallel to this is the care with which Nature secures the nourishment of the embryon plant, or the chick in the egg. The lobes of a bean or a pea, and of most seeds, consist of a deposit of nutritious matter, and when heat and moisture favor the developement of the living property, vessels which are scattered in these lobes or cotyledons commence absorption of the matter, and carry it to the centre of the plant. It is remarkable, that these lobes, having thus, in the first instance, supplied the young plant with nutritious matter, change their office, and, rising above the surface, become the first leaves. Thus we see how the *nourishment is supplied*, until the radicle is pushed down into the

But in the argument before us, we are entitled to consider, not only animal bodies when framed, but the circumstances under which they are framed: and, in this view of the subject, the constitution of many of their parts, is most strictly prospective.

III. The eye is of no use, at the time when it is formed. It is an optical instrument, made in a dungeon; constructed for the refraction of light to a focus, and perfect for its purpose, before a ray of light has had access to it; geometrically adapted to the properties and action of an element, with which it has no communication. It is about, indeed, to enter into that communication; and this is precisely the thing, which evidences intention. It is *providing* for the *future*, in the closest sense which can be given to these terms; for it is providing for a future change; not for the then subsisting condition of the animal; not for any gradual progress or advance in that same condition; but for a new state, the consequence of a great and sudden alteration, which the animal is to undergo at its birth. Is it to be believed, that the eye was formed, or, which is the same thing, that the series of causes was fixed, by which the eye is formed, without a view to this change; without a prospect of that condition, in which its fabric, of no use at present, is about to be of the greatest; without a consideration of the qualities of that element, hitherto entirely excluded, but with which it was hereafter to hold so intimate a relation? A young man makes a pair of spectacles, for himself, against he grows old; for which spectacles, he has no want or use, whatever, at the time he makes them. Could this be done, without knowing and considering the defect of vision to which advanced age is subject? Would not the precise suitableness of the instrument to its purpose, of the remedy to the defect,

earth, and the leaves receive the influence of the atmosphere. So in the chick, the white or albumen of the egg, goes to its nourishment, whilst it is in the shell; but the yolk of the egg, is embraced in the body of the chick, when excluded from the shell, and a duct leads from the membrane, enclosing this mass of nutriment, into the first intestine. And thus is the chick nourished, not only whilst included in the shell, but also, during its first feeble existence, a period which corresponds with that of lactation in mammalia.—Eng. Ed.

of the convex lens to the flattened eye, establish the certainty of the conclusion, that the case, afterwards to arise, had been considered beforehand, speculated upon, provided for ? all which are exclusively the acts of a reasoning mind. The eye, formed in one state, for use only in another state, and in a different state, affords a proof, no less clear, of destination to a future purpose; and a proof, proportionably stronger, as the machinery is more complicated, and the adaptation more exact.

IV. What has been said of the eye, holds equally true of the lungs. Composed of air-vessels, where there is no air; elaborately constructed for the alternate admission and expulsion of an elastic fluid, where no such fluid exists; this great organ, with the whole apparatus belonging to it, lies collapsed in the fœtal thorax; yet in order, and in readiness for action, the first moment that the occasion requires its service. This is having a machine locked up, in store, for future use; which incontestably proves, that the case was expected to occur, in which this use might be experienced; but expectation is the proper act of intelligence. Considering the state in which an animal exists, before its birth, I should look for nothing less in its body, than a system of lungs. It is like finding a pair of bellows, in the bottom of the sea; of no sort of use, in the situation in which they are found; formed for an action which was impossible to be exerted; holding no relation or fitness to the element which surrounds them, but both to another element, in another place.

As part and parcel of the same plan, ought to be mentioned, in speaking of the lungs, the provisionary contrivances of the *foramen ovale* and *ductus arteriosus*. In the fœtus, pipes are laid for the passage of the blood through the lungs; but, until the lungs be inflated, by the inspiration of air, that passage is impervious, or in a great degree obstructed. What, then, is to be done ? What would an artist, what would a master, do upon the occasion ? He would endeavor, most probably, to provide a *temporary* passage, which might carry on the communication required, until the other was open. Now this is the thing, which is *actually* done in the heart. Instead of the cir-

cuitous route, through the lungs, which the blood afterwards takes, before it gets from one auricle of the heart to the other, a portion of the blood passes immediately from the right auricle to the left, through a hole, placed in the partition which separates these cavities. This hole, anatomists call the *foramen ovale*. There is, likewise, another cross cut, answering the same purpose, by what is called the *ductus arteriosus*, lying between the pulmonary artery and the aorta. But both expedients are so strictly temporary, that, after birth, the one passage is closed, and the tube which forms the other, shrivelled up into a ligament. If this be not contrivance, what is?

But, forasmuch as the action of the air upon the blood in the lungs appears to be necessary to the perfect concoction of that fluid, *i. e.*, to the life and health of the animal, (otherwise the shortest route might still be the best,) how comes it to pass that the *fœtus* lives, and grows, and thrives without it? The answer is, that the blood of the fœtus is the mother's; that it has undergone that action in her habit; that one pair of lungs serves for both. When the animals are separated, a new necessity arises; and to meet this necessity, as soon as it occurs, an organization is prepared. It is ready for its purpose; it only waits for the atmosphere; it begins to play the moment the air is admitted to it.[47]

[47] Does not the whole condition of the embryon go to this argument? At first there is a mere jelly, or what appears as such; a little further advanced, and there are bones, and muscles, and nerves. But these lie quite inactive, for a long term; the nerves excite to no action; the muscles do not move: the joints are not exercised, they are perfected slowly. The period of full developement, is not arrived; they have not yet their stimulus to activity. The whole, then, is in a state of preparation. Conduit pipes without their fluids, glands and ducts without their secretions, sensibilities dormant, and a mechanism quite inoperative; a whole animal system beautifully contrived, but only in "prospective contrivance."

CHAPTER XV.

RELATIONS.

When several different parts contribute to one effect; or, which is the same thing, when an effect is produced by the joint action of different instruments; the fitness of such parts or instruments to one another for the purpose of producing, by their united action, the effect, is what I call *relation;* and wherever this is observed, in the works of Nature or of man, it appears to me to carry along with it decisive evidence of understanding, intention, art. In examining, for instance, the several parts of a *watch*, the spring, the barrel, the chain, the fusee, the balance, the wheels of various sizes, forms, and positions, what is it which would take an observer's attention as most plainly evincing a construction, directed by thought, deliberation, and contrivance? It is the suitableness of these parts to one another; first, in the succession and order in which they act; and, secondly, with a view to the effect finally produced. Thus, referring the spring to the wheels, our observer sees in it that which originates and upholds *their* motion; in the chain, that which transmits the motion to the fusee; in the fusee, that which communicates it to the wheels; in the conical figure of the fusee, if he refer to the spring, he sees that which corrects the inequality of its force. Referring the wheels to one another, he notices, first, their teeth, which would have been without use or meaning if there had been only one wheel, or if the wheels had had no connexion between themselves, or common bearing upon some joint effect; secondly, the correspondency of their position, so that the teeth of one wheel catch into the teeth of another; thirdly, the proportion observed in the number of teeth in each wheel, which determines the rate of going. Referring the balance to the rest of the works, he saw, when he came to understand its action, that which rendered *their* motions equable. Lastly, in looking upon

the index and face of the watch, he saw the use and conclusion of the mechanism, viz., marking the succession of minutes and hours; but all depending upon the motions within, all upon the system of intermediate actions between the spring and the pointer. What thus struck his attention in the several parts of the watch, he might probably designate by one general name of "relation;" and observing, with respect to all cases whatever, in which the origin and formation of a thing could be ascertained by evidence, that these relations were found in things produced by art and design, and in no other things, he would rightly deem them characteristic of such productions.

To apply the reasoning here described, to the works of Nature—the animal economy is full, is made up, of these *relations*.

I. There are, first, what in one form or other belong to all animals, the parts and powers which successively act upon their *food*. Compare this action with the process of a manufactory. In men and quadrupeds the aliment is first broken and bruised by mechanical instruments of mastication, viz., sharp spikes or hard knobs, pressing against or rubbing upon one another; thus ground and comminuted it is carried by a pipe into the stomach, where it waits to undergo a great chemical action, which we call digestion: when digested, it is delivered through an orifice, which opens and shuts, as there is occasion, into the first intestine; there, after being mixed with certain proper ingredients, poured through a hole in the side of the vessel, it is further dissolved: in this state the milk, chyle, or part which is wanted, and which is suited for animal nourishment, is strained off by the mouths of very small tubes opening into the cavity of the intestines; thus freed from its grosser parts, the percolated fluid is carried by a long, winding, but traceable course, into the main stream of the old circulation; which conveys it in its progress to every part of the body. Now I say again, compare this with the process of a manufactory, with the making of cider, for example; with the bruising of the *apples in the* mill, the squeezing of them when so bruised

in the press, the fermentation in the vat, the bestowing of the liquor, thus fermented, in the hogsheads, the drawing off into bottles, the pouring out for use into the glass. Let any one show me any difference, between these two cases, as to the point of contrivance. That which is at present under our consideration, the "relation" of the parts successively employed, is not more clear in the last case than in the first. The aptness of the jaws and teeth, to prepare the food for the stomach, is, at least, as manifest as that of the cider-mill to crush the apples for the press. The concoction of the food in the stomach, is as necessary for its future use, as the fermentation of the stum in the vat is to the perfection of the liquor. The disposal of the aliment afterwards, the action and change which it undergoes, the route which it is made to take, in order that, and until that, it arrive at its destination, is more complex, indeed, and intricate ; but, in the midst of complication and intricacy, as evident and certain as is the apparatus of cocks, pipes, tunnels, for transferring the cider from one vessel to another ; of barrels and bottles for preserving it till fit for use, or of cups and glasses, for bringing it, when wanted, to the lip of the consumer. The character of the machinery is, in both cases, this ; that one part, answers to another part, and every part to the final result.

This parallel, between the alimentary operation and some of the processes of art, might be carried further into detail. Spallanzani has remarked a circumstantial resemblance, between the stomachs of gallinaceous fowls and the structure of *corn-mills*. Whilst the two sides of the gizzard perform the office of the millstones, the craw or crop supplies the place of the *hopper*.

When our fowls are abundantly supplied with meat, they soon fill their craw ; but it does not immediately pass thence into the gizzard ; it always enters in very small quantities, in proportion to the progress of trituration, in like manner as, in a mill, a receiver is fixed above the two large stones which serve for grinding the corn, which receiver, although the corn be put into it in bushels, allows the grain to dribble only in small quantities into the *central hole in the* upper millstone.

But we have not done with the alimentary history. There subsists a general *relation* between the external organs of an animal by which it procures its food, and the internal powers by which it digests it. Birds of prey, by their talons and beaks, are qualified to seize and devour many species both of other birds and of quadrupeds. The constitution of the stomach, agrees exactly with the form of the members. The gastric juice of a bird of prey, of an owl, a falcon, or a kite, acts upon the animal fibre alone ; it will not act upon seeds or grasses at all. On the other hand, the conformation of the mouth of the sheep, or the ox, is suited for browsing upon herbage. Nothing about these animals is fitted for the pursuit of living prey. Accordingly, it has been found by experiments, tried not many years ago, with perforated balls, that the gastric juice of ruminating animals, such as the sheep and the ox, speedily dissolves vegetables, but makes no impression upon animal bodies. This accordancy is still more particular. The gastric juice, even of granivorous birds, will not act upon the grain, whilst whole and entire. In performing the experiment, of digesting with the gastric juice, in vessels, the grain must be crushed and bruised, before it be submitted to the menstruum, that is to say, must undergo by art, without the body, the preparatory action, which the gizzard exerts upon it within the body, or no digestion will take place. So strict, in this case, is the relation between the offices assigned to the digestive organ, between the mechanical operation and the chemical process.

II. The relation of the kidneys to the bladder, and of the ureters to both, *i. e.*, of the secreting organ, to the vessel receiving the secreted liquor, and the pipe laid from one to the other, for the purpose of conveying it from one to the other, is as manifest, as it is amongst the different vessels employed in a distillery, or in the communications between them. The animal structure, in this case, being simple, and the parts easily separated, it forms an instance of correlation which may be presented, by dissection, to every eye, or which, indeed, without dissection, is capable of being apprehended by every un-

derstanding. This correlation of instruments to one another, fixes intention some where. Especially when every other solution is negatived by the conformation. If the bladder had been merely an expansion of the ureter, produced by retention of the fluid, there ought to have been a bladder for each ureter. One receptacle, fed by two pipes issuing from different sides of the body, yet from both conveying the same fluid, is not to be accounted for by any such supposition as this.

III. Relation of parts to one another accompanies us throughout the whole animal economy. Can any relation be more simple, yet more convincing than this, that the eyes are so placed as to look in the direction in which the legs move and the hands work? It might have happened very differently, if it had been left to chance. There were at least three quarters of the compass, out of four, to have erred in. Any considerable alteration, in the position of the eye or the figure of the joints, would have disturbed the line, and destroyed the alliance between the sense and the limbs.

IV. But relation, perhaps, is never so striking as when it subsists, not between different parts of the same thing, but between different things. The relation between a lock and a key is more obvious, than it is between different parts of a lock. A bow was designed for an arrow, and an arrow for a bow; and the design is more evident, for their being separate implements.

Nor do the works of the Deity want this clearest species of relation. The *sexes* are manifestly made for each other. They form the grand relation of animated nature, universal, organic, mechanical, subsisting, like the clearest relations of art, in different individuals, unequivocal, inexplicable without design.

So much so, that, were every other proof of contrivance in Nature, dubious or obscure, this alone would be sufficient. The example is complete. Nothing is wanting to the argument. I see no way whatever of getting over it.

V. The teats of animals, which give suck, bear a *relation to the mouth* of the suckling progeny, particularly

to the lips and tongue. Here also, as before, is a correspondency of parts, which parts subsist in different individuals.

- These are *general* relations, or the relations of parts which are found either in all animals, or in large classes and descriptions of animals. *Particular* relations, or the relations which subsist between the particular configuration of one or more parts of certain species of animals, and the particular configuration of one or more other parts of the same animal, (which is the sort of relation that is, perhaps, most striking,) are such as the following :

I. In the *swan*, the web-foot, the spoon-bill, the long neck, the thick down, the graminivorous stomach, bear all a relation to one another, inasmuch as they all concur in one design, that of supplying the occasions of an aquatic fowl, floating upon the surface of shallow pools of water, and seeking its food at the bottom. Begin with any one of these particularities of structure, and observe how the rest follow it. The web-foot, qualifies the bird for swimming ; the spoon-bill, enables it to graze. But how is an animal, floating upon the surface of pools of water, to graze at the bottom, except by the mediation of a long neck ? A long neck, accordingly, is given to it. Again, a warm-blooded animal which was to pass its life upon water, required a defence against the coldness of that element. Such a defence is furnished to the swan in the muff in which its body is wrapped. But all this outward apparatus would have been in vain, if the intestinal system had not been suited to the digestion of vegetable substances. I say suited to the digestion of vegetable substances ; for it is well known that there are two intestinal systems found in birds : one with a membranous stomach and a gastric juice, capable of dissolving animal substances alone—the other with a crop and gizzard calculated for the moistening, bruising, and afterwards digesting, of vegetable aliment.

Or set off with any other distinctive part in the body of the swan ; for instance, with the long neck. The long

neck, without the web-foot, would have been an encumbrance to the bird; yet there is no necessary connexion between a long neck and a web-foot. In fact they do not usually go together. How happens it, therefore, that they meet only when a particular design demands the aid of both?

II. This mutual relation, arising from a subserviency to a common purpose, is very observable, also, in the parts of a *mole*. The strong short legs of that animal, the palmated feet, armed with sharp nails, the pig-like nose, the teeth, the velvet coat, the small external ear, the sagacious smell, the sunk protected eye, all conduce to the utilities or to the safety of its under-ground life. It is a special purpose, specially consulted throughout. The form of the feet, fixes the character of the animal. They are so many shovels; they determine its action to that of rooting in the ground; and every thing about its body agrees with this destination. The cylindrical figure of the mole, as well as the compactness of its form, arising from the terseness of its limbs, proportionably lessens its labor; because, according to its bulk, it thereby requires the least possible quantity of earth to be removed for its progress. It has nearly the same structure of the face and jaws as a swine, and the same office for them. The nose is sharp, slender, tendinous, strong, with a pair of nerves going down to the end of it. The plush covering, which, by the smoothness, closeness, and polish of the short piles that compose it, rejects the adhesion of almost every species of earth, defends the animal from cold and wet, and from the impediment which it would experience by the mould sticking to its body. From soils of all kinds, the little pioneer comes forth bright and clean. Inhabiting dirt, it is of all animals the neatest.

But what I have always most admired in the mole, is its *eyes*. This animal occasionally visiting the surface, and wanting, for its safety and direction, to be informed when it does so, or when it approaches it, a perception of light was necessary. I do not know that the clearness of sight depends at all upon the size of the organ. What is gained by the largeness or prominence of the

globe of the eye, is width in the field of vision. Such a capacity would be of no use to an animal which was to seek its food in the dark. The mole did not want to look about it ; nor would a large advanced eye have been easily defended from the annoyance to which the life of the animal must constantly expose it. How indeed was the mole, working its way under ground, to guard its eyes at all ? In order to meet this difficulty, the eyes are made scarcely larger than the head of a corking-pin ; and these minute globules are sunk so deeply in the skull, and lie so sheltered within the velvet of its covering, as that any contraction of what may be called the eyebrows, not only closes up the apertures which lead to the eyes, but presents a cushion, as it were, to any sharp or protruding substance which might push against them. This aperture, even in its ordinary state, is, like a pinhole in a piece of velvet, scarcely pervious to loose particles of earth.

Observe, then, in this structure, that which we call relation. There is no natural connexion between a small, sunk eye, and a shovel, palmated foot. Palmated feet might have been joined with goggle eyes ; or small eyes might have been joined with feet of any other form. What was it, therefore, which brought them together in the mole ? That which brought together the barrel, the chain, and the fusee in a watch—design ; and design in both cases inferred, from the relation which the parts bear to one another, in the prosecution of a common purpose. As hath already been observed, there are different ways of stating the relation, according as we sat out from a different part. In the instance before us, we may either consider the shape of the feet, as qualifying the animal for that mode of life and inhabitation to which the structure of its eyes confines it ; or we may consider the structure of the eye as the only one which would have suited with the action to which the feet are adapted. The relation is manifest, whichever of the parts related we place first in the order of our consideration. In a word, the feet of the mole are made for digging : the neck, nose, eyes, ears, and skin, are peculiarly adapted to an under-ground life ; and this is what I call relation.

CHAPTER XVI.

COMPENSATION.

COMPENSATION is a species of relation. It is relation when the *defects* of one part, or of one organ, are supplied by the structure of another part, or of another organ. Thus—

I. The short unbending neck of the *elephant* is compensated by the length and flexibility of his *proboscis*. He could not have reached the ground without it; or, if it be supposed that he might have fed upon the fruit, leaves, or branches of trees, how was he to drink? Should it be asked, why is the elephant's neck so short? it may be answered, that the weight of a head so heavy could not have been supported at the end of a longer lever. To a form, therefore, in some respects necessary, but in some respects, also, inadequate to the occasion of the animal, a supplement is added, which exactly makes up the deficiency under which he labored.

If it be suggested, that this proboscis may have been produced, in a long course of generations, by the constant endeavor of the elephant to thrust out its nose, (which is the general hypothesis by which it has lately been attempted to account for the forms of animated nature,) I would ask, How was the animal to subsist in the mean time—during the process—*until* this prolongation of snout were completed? What was to become of the individual, whilst the species was perfecting? [48]

[48] Whilst we have before us the daily proof of the capacities of animals for domestication, in considering their structure and their instincts, we must look back into that long period before man's creation, when they had not his protection and care. A thousand concurring testimonies prove, that there were periods when the earth's surface was more suitable for brutes than it was for the abode of man; and when they were grouped together, each species with its enemy, and each with a power of preservation, at once to prevent too great an increase and total extermination. The young horse, which in his paddock has neither known bad treatment nor an enemy, will yet shiver and

Our business at present is, simply to point out the relation which this organ bears to the peculiar figure of the animal to which it belongs. And herein all things correspond. The necessity of the elephant's proboscis, arises from the shortness of his neck: the shortness of the neck is rendered necessary, by the weight of the head. Were we to enter into an examination of the structure and anatomy of the proboscis itself, we should see in it one of the most curious of all examples of animal mechanism. The disposition of the ringlets and fibres, for the purpose, first, of forming a long cartilaginous pipe; secondly, of contracting and lengthening that pipe; thirdly, of turning it in every direction at the will of the animal; with the superaddition at the end, of a fleshy production, of about the length and thickness of a finger, and performing the office of a finger, so as to pick up a straw from the ground. These properties of the same organ, taken together, exhibit a specimen, not only of design, (which is attested by the advantage,) but of consummate art, and, as I may say, of elaborate preparation, in accomplishing that design.

II. The hook in the wing of a *bat*, is strictly a mechanical, and, also, a *compensating* contrivance. At the angle of its wing, there is a bent claw, exactly in the form

start away from a brindled swine, or any animal that is bristled or rough.

Geological researches, so happily combined with comparative anatomy, give us no room to conjecture that there has been any thing like a progressive improvement in the species of animals. They have been created with all the characters in which they are now propagated; and had it been otherwise, the species would have become extinct, or they would have lost their place in that balance of offence and defence by which it has pleased the Creator to provide for their continuance.

One would imagine that an idea so wild, as that an animal should produce the variety of organs or external instruments which we see, by an effort—an energy proceeding from itself, could never have been maintained in an age like the present, when it is so fully proved that there is no change upon the extremity of an animal, no additional organ like this of the trunk of an elephant, no variety in its paw or its hoof, but what is attended with a corresponding alteration in the whole system of the creature—of its bones, its teeth, its stomach, as well as in its appetites and desires.—Eng. Ed.

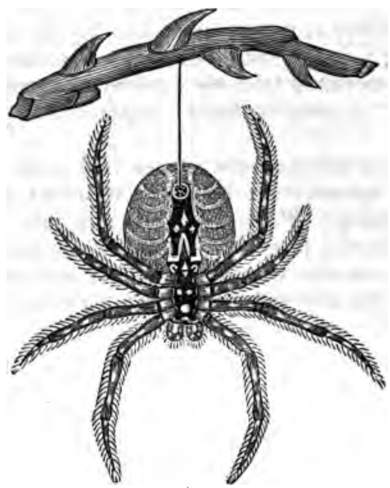
of a hook, by which the bat attaches itself to the sides of rocks, caves, and buildings, laying hold of crevices, joinings, chinks, and roughnesses. It hooks itself by this claw; remains suspended by this hold; takes its flight from this position: which operations compensate for the decrepitude of its legs and feet. Without her hook, the bat would be the most helpless of all animals. She can neither run upon her feet, nor raise herself from the ground. These inabilities are made up to her by the contrivance in her wing; and in placing a claw on that part, the Creator has deviated from the analogy observed in winged animals. A singular defect required a singular substitute.

III. The *crane*-kind are to live and seek their food amongst the waters; yet, having no web-foot, are incapable of swimming. To make up for this deficiency, they are furnished with long legs for wading, or long bills for groping, or usually with both. This is *compensation.* But I think the true reflection upon the present instance is, how every part of nature is tenanted by appropriate inhabitants. Not only is the surface of deep waters peopled by numerous tribes of birds that swim, but marshes and shallow pools are furnished with hardly less numerous tribes of birds that wade.

IV. The common *parrot* has, in the structure of its beak, both an inconveniency and a *compensation* for it. When I speak of an inconveniency I have a view to a dilemma which frequently occurs in the works of nature, viz., that the peculiarity of structure, by which an organ is made to answer one purpose, necessarily unfits it for some other purpose. This is the case before us. The upper bill of the parrot is so much hooked, and so much overlaps the lower, that if, as in other birds, the lower chap alone had motion, the bird could scarcely gape wide enough to receive its food; yet this hook, and overlapping of the bill, could not be spared, for it forms the very instrument by which the bird climbs,—to say nothing of the use which it makes of it in breaking nuts and the hard substances upon which it feeds. How, therefore, has Nature *provided for* the opening of this occluded mouth?

By making the upper chap movable, as well as the lower. In most birds, the upper chap is connected, and makes but one piece, with the skull; but in the parrot, the upper chap is joined to the bone of the head by a strong membrane placed on each side of it, which lifts and depresses it at pleasure.*

V. The *spider's web* is a *compensating* contrivance.



The spider lives upon flies, without wings to pursue them; a case, one would have thought, of great difficulty, yet provided for, and provided for by a resource which no stratagem, no effort of the animal could have produced, had not both its external and internal structure been specifically adapted to the operation.[49]

[49] There are few things better suited to remove the disgust, into which young people are betrayed, on the view of some natural objects, than this of the spider. They will find that the most despised creature, may become a subject of admiration, and be selected by the naturalist to exhibit the marvellous works of the creation. The terms given to these insects, lead us to expect interesting particulars concerning them, since they have been divided into vagrants, hunters, swimmers, and water spiders, sedentary, and mason spiders; thus evincing a variety in their condition, activity, and mode of life; and we cannot be sur

* *Goldsmith's* Nat. Hist. vol. v. p. 274.

VI. In many species of insects the eye is fixed, and consequently without the power of turning the pupil to the object. This great defect is, however, perfectly *compensated*, and by a mechanism which we should not suspect. The eye is a multiplying-glass, with a lens

prised to find them varying in the performance of their vital functions, (as, for example, in their mode of breathing,) as well as in their extremities and instruments. Of these instruments, the most striking is the apparatus for spinning and weaving, by which they not only fabricate webs to entangle their prey, but form cells for their residence and concealment; sometimes living in the ground, sometimes under water, yet breathing the atmosphere. Corresponding with their very singular organization, are their instincts. We are familiar with the watchfulness and voracity of some spiders, when their prey is indicated by the vibration of the cords of their network. Others, have the eye and disposition of the lynx or tiger, and after couching in concealment, leap upon their victims. Some conceal themselves under a silken hood or tube, six eyes only projecting. Some bore a hole in the earth, and line it as finely as if it were done with the trowel and mortar, and then hang it with delicate curtains. A very extraordinary degree of contrivance is exhibited in the trap-door spider. This door, from which it derives its name, has a frame and hinge on the mouth of the cell, and is so provided that the claw of the spider can lay hold of it, and whether she enters or goes out, says Mr. Kirby, the door shuts of itself. But the water spider, has a domicile more curious still: it is under water, with an opening at the lower part for her exit and entrance; and although this cell be under water, it contains air like a diving-bell, so that the spider breathes the atmosphere. The air is renewed in the cell in a manner not easily explained. The spider comes to the surface; a bubble of air is attracted to its body; with this air, she descends, and gets under her cell, when the air is disengaged, and rises into the cell; and thus, though under water, she lives in the air. There must be some peculiar property of the surface of this creature by which she can move in the water, surrounded with an atmosphere, and live under the water, breathing the air.

The chief instrument, by which the spider performs these wonders, is the spinning apparatus. The matter from which the threads are spun is a liquid contained in cells; the ducts from these cells open upon little projecting teats, and the atmosphere has so immediate an effect upon this liquid, that upon exposure to it, the secretion becomes a tough and strong thread. Twenty-four of these fine strands form together a thread of the thickness of that of the silkworm. We are assured, that there are three different sorts of material thus produced, which are indeed required for the various purposes to which they are applied—as, for example, to mix up with the earth to form the cells; to line these cells as with fine cotton; to make light and floating threads, by which they may be conveyed through the air, as well as those meshes which are so geometrically and correctly formed to entrap their prey.—Eng. Ed.

looking in every direction, and catching every object. By which means, although the orb of the eye be stationary, the field of vision is as ample as that of other animals, and is commanded on every side. When this lattice-work was first observed, the multiplicity and minuteness of the surfaces must have added to the surprise of the discovery. Adams tells us, that fourteen hundred of these reticulations have been counted in the two eyes of a drone-bee.

In other cases, the *compensation* is effected by the number and position of the eyes themselves. The spider has eight eyes, mounted upon different parts of the head; two in front, two in the top of the head, two on each side. These eyes are without motion, but, by their situation, suited to comprehend every view which the wants or safety of the animal rendered it necessary for it to take.

VII. 'The Memoirs for the Natural History of Animals,' published by the French Academy, A. D. 1687, furnish us with some curious particulars in the eye of a cameleon. Instead of two eyelids, it is covered by an eyelid with a hole in it. This singular structure appears to be *compensatory*, and to answer to some other singularities in the shape of the animal. The neck of the cameleon is inflexible. To make up for this, the eye is so prominent, that more than half of the ball stands out of the head; by means of which extraordinary projection, the pupil of the eye can be carried by the muscles in every direction, and is capable of being pointed towards every object. But then, so unusual an exposure of the globe of the eye requires, for its lubricity and defence, a more than ordinary protection of eyelid, as well as a more than ordinary supply of moisture: yet the motion of an eyelid, formed according to the common construction, would be impeded, as it should seem, by the convexity of the organ. The aperture in the lid meets this difficulty. It enables the animal to keep the principal part of the surface of the eye under cover, and to preserve it in a due state of humidity without shutting out the light, or without performing every moment a nictitation, which it

is probable would be more laborious to this animal than to others.

VIII. In another animal, and in another part of the animal economy, the same 'Memoirs' describe a most remarkable *substitution*. The reader will remember what we have already observed, concerning the *intestinal* canal —that its length, so many times exceeding that of the body, promotes the extraction of the chyle from the aliment, by giving room for the lacteal vessels to act upon it through a greater space. This long intestine, wherever it occurs, is in other animals disposed in the abdomen from side to side, in returning folds. But in the animal now under our notice the matter is managed otherwise. The same intention is mechanically effectuated, but by a mechanism of a different kind. The animal of which I speak is an amphibious quadruped, which our authors call the alopecias or sea-fox.* The intestine is straight from one end to the other; but in this straight and consequently short intestine, is a winding, corkscrew, spiral passage, through which the food, not without several circumvolutions, and in fact by a long route, is conducted to its exit. Here the shortness of the gut is *compensated* by the obliquity of the perforation.

IX. But the works of the Deity are known by *expedients*. Where we should look for absolute destitution —where we can reckon up nothing but wants—some contrivance always comes in to supply the privation. A *snail*, without wings, feet, or thread, climbs up the stalks of plants by the sole aid of a viscid humor, discharged from her skin. She adheres to the stems, leaves, and fruits of plants by means of a sticking-plaster. A *mussel*, which might seem by its helplessness to lie at the mercy of every wave that went over it, has the singular power of spinning strong tendinous threads, by which she moors her shell to rocks and timbers. A *cockle*, on the contrary, by means of its stiff tongue, works for itself a shelter in the sand. The provisions of Nature extend to cases the most desperate. A *lobster* has in its constitu-

* [This is a species of *shark*, called by naturalists, *Squalus vulpes*, and not a quadruped as stated in the text.—AM. ED.]

tion a difficulty so great, that one could hardly conjecture beforehand how Nature would dispose of it. In most animals the skin grows with their growth. If, instead of a soft skin, there be a shell, still it admits of a gradual enlargement. If the shell, as in the tortoise, consist of several pieces, the accession of substance is made at the sutures. Bivalve shells grow bigger by receiving an accretion at their edge ; it is the same with spiral shells at their mouth. The simplicity of their form admits of this. But the lobster's shell, being applied to the limbs of the body, as well as to the body itself, allows not of either of the modes of growth which are observed to take place in other shells. Its hardness resists expansion ; and its complexity renders it incapable of increasing its size by addition of substance to its edge. How then was the growth of the lobster to be provided for ? Was room to be made for it in the old shell, or was it to be successively fitted with new ones ? If a change of shell became necessary, how was the lobster to extricate himself from his present confinement ? how was he to uncase his buckler, or draw his legs out of his boots ? The process which fishermen have observed to take place, is as follows. At certain seasons the shell of the lobster grows soft ; the animal swells its body ; the seams open, and the claws burst at the joints. When the shell has thus become loose upon the body, the animal makes a second effort, and by a tremulous, spasmodic motion casts it off. In this state, the liberated but defenceless fish retires into holes in the rock. The released body now suddenly pushes its growth. In about eight-and-forty hours, a fresh concretion of humor upon the surface, *i. e.*, a new shell, is formed, adapted in every part to the increased dimensions of the animal. This wonderful mutation is repeated every year.

If there be imputed defects without compensation, I should suspect that they were defects only in appearance. Thus, the body of the *sloth* has often been reproached for the slowness of its motions, which has been attributed to an imperfection in the formation of its limbs. But it ought to be observed, that it is this slownoss which alone

suspends the voracity of the animal. He fasts during his migration from one tree to another: and this fast may be necessary for the relief of his overcharged vessels, as well as to allow time for the concoction of the mass of coarse and hard food which he has taken into his stomach. The tardiness of his pace seems to have reference to the capacity of his organs, and to his propensities with respect to food—*i. e.*, is calculated to counteract the effects of repletion.*

Or there may be cases in which a defect is artificial, and compensated by the very cause which produces it. Thus the *sheep*, in the domesticated state in which we see it, is destitute of the ordinary means of defence or escape—is incapable either of resistance or flight. But this is not so with the wild animal. The natural sheep is swift and active; and, if it lose these qualities when it comes under the subjection of man, the loss is compensated by his protection. Perhaps there is no species of quadruped whatever, which suffers so little as this does, from the depredation of animals of prey.

For the sake of making our meaning better understood, we have considered this business of compensation under certain *particularities* of constitution in which it appears to be most conspicuous. This view of the subject necessarily limits the instances to single species of animals. But there are compensations, perhaps not less certain, which extend over large classes, and to large portions of living nature.

* ["Blumenbach states, in his Manual of Natural History," says Paxton, "that he had conversed with many Hollanders who had lived in Guiana, and from them collected, that this apparently miserable animal, is rather an enviable one. First, he nourishes himself entirely from leaves; and, therefore, when he has once climbed a tree, he can live on the same dish a quarter of a year. Secondly, he does not drink at all. Thirdly, on a tree he is exposed to but few enemies, and when the sloth marks that a tiger-cat is climbing up a branch, it goes softly to the end of the branch, and rocks it till it falls off, so that seldom is there an instance that a tiger-cat surprises one; even upon the ground, so powerful are the claws of the sloth, and so fearful its cries, that its enemies generally get the worst. So idle is Buffon's declamation against the goodness and wisdom of Providence drawn from this beast."—AM. ED.]

I. In quadrupeds, the deficiency of teeth is usually *compensated* by the faculty of rumination. The sheep, deer, and ox tribe are without fore-teeth in the upper jaw. These ruminate. The horse and ass are furnished with teeth in the upper jaw, and do not ruminate. In the former class, the grass and hay descend into the stomach, nearly in the state in which they are cropped from the pasture, or gathered from the bundle. In the stomach they are softened by the gastric juice, which, in these animals, is unusually copious: thus softened and rendered tender, they are returned a second time to the action of the mouth, where the grinding teeth complete at their leisure the trituration which is necessary, but which was before left imperfect; I say the trituration which is necessary: for it appears from experiments that the gastric fluid of sheep, for example, has no effect in digesting plants unless they have been previously masticated; that it only produces a slight maceration, nearly as common water would do in a like degree of heat; but that when once vegetables are reduced to pieces by mastication, the fluid then exerts upon them its specific operation. Its first effect is to soften them, and to destroy their natural consistency: it then goes on to dissolve them, not sparing even the toughest parts, such as the nerves of the leaves.*

I think it very probable, that the gratification also of the animal is renewed and prolonged by this faculty. Sheep, deer, and oxen appear to be in a state of enjoyment whilst they are chewing the cud: it is then, perhaps, that they best relish their food.[50]

[50] Wherever a seed can lodge we find vegetables growing; and wherever we find digestible matter there are animals to live upon it; and the kind of food determines the organization of the creature, not resulting from it, but provided for it. The class of ruminants feed on the coarser herbage where the vegetable is in abundance, but the actual nutritious matter is small in quantity compared with the mass. There is, therefore, an obvious necessity for a more complex apparatus to extract the smaller proportion of matter capable of being animalized: hence the maceration in the first stomach, hence the regurgitation and rumination, and the reception into the second and third stomach, in preparation for the proper digestion in the last. When the mass is

* Spall. Dis. iii. sect. cxl.

II. In birds, the *compensation* is still more striking. They have no teeth at all. What have they then to make up for this severe want? I speak of granivorous and herbivorous birds: such as common fowls, turkeys, ducks, geese, pigeons, &c.; for it is concerning these alone that the question need be asked. All these are furnished with a peculiar and most powerful muscle, called the *gizzard*; the inner coat of which is fitted up with rough plaits, which, by a strong friction against one another, break and grind the hard aliment as effectually, and by the same mechanical action, as a coffee-mill would do. It has been proved by the most correct experiments, that the gastric juice of these birds will not operate upon the *entire* grain: not even when softened by water, or macerated in the crop. Therefore, without a grinding machine within its body, without the trituration of the gizzard, a chicken would have starved upon a heap of corn. Yet, why should a bill and a gizzard go together? why should a gizzard never be found where there are teeth?

Nor does the gizzard belong to birds as such. A gizzard is not found in birds of prey: *their* food requires not to be ground down in a mill. The compensatory contrivance goes no further than the necessity. In both classes of birds, however, the digestive organ within the body bears a strict and mechanical relation to the external instruments for procuring food. The soft membranous stom-

digested, the nutritious part is still small in proportion to the whole; and to permit that smaller portion of aliment to be absorbed and carried into the system, the intestinal canal must be long and complex, offering resistance to the rapid descent of the food, and giving it lodgement: and thus there is always a correspondence between the complication of the stomach and the length of the intestines, and between both and the nature of the food. It is further very remarkable, that when animals of the same species live in different climates, where there is more or less abundance of vegetable food, there is an adaptation of their digestive organs. Where it is abundant, the configuration of the intestines, which is intended to delay its descent, is less complex. Where the food is more scarce, the intestine is longer, and the valvular obstruction greater. This has been observed by Sir E. Home, in comparing the cassowary of Java with the cassowary of New South Wales, and the American ostrich with the same bird inhabiting the deserts of Africa. The same comparison has been made, between the Leicestershire sheep and the mountain sheep of Scotland.—Eng. Ed.

ach, accompanies a hooked notched beak; short muscular legs; strong, sharp, crooked talons:—the cartilaginous stomach attends that conformation of bill and toes, which restrains the bird to the picking of seeds or the cropping of plants.[51]

[OF THE GIZZARD.

The gizzard is a favorite illustration with our author; he takes it up in Chapters x. xii. xv. xvi., as the example of compensation, relation, &c.

The bill of a bird has extensive relations both externally and internally. When we see a bird trimming his feathers with his bill, and combing out each feather from the root to the point, we cannot but observe, that admirably as feathers are formed for flight and for protection against cold and wet, they would be inconsistent with the tongue and teeth of the quadruped. The rough tongue would not penetrate to their interstices; nor would the

[51] We have said, that it is the object to support animal life, and to give the enjoyment of existence; and that wherever the means are afforded of converting a material under the processes of digestion and assimilation, there animals will be found with an apparatus of digestion adapted to the food. Nothing certainly can be more curious than the vicarious action of the stomach and mouth. We see, for example, that where the bill precludes mastication in the mouth, it is performed in the stomach; and then muscles are found in the stomach as powerful as those of the jaws and teeth; and as to the teeth, or what is equivalent to them, we may say that they are continually renewed. In fact, no mechanical structure of jaws and teeth could answer the purposes of Nature here: no union of bone and enamel in the tooth could have withstood the attrition of the gizzard; and one of the most beautiful and interesting appliances of Nature is the substitution, through the instinct of the animal, of small stones of hard texture, generally consisting of silex, introduced within the grasp and action of this organ. It is a further proof that the mastication, if we may use the term, is more perfect in the gizzard than where there is the most complex structure of teeth, and therefore that it is the means of extracting the greater quantity of nutritious matter. Accordingly, there are gizzards in most classes of animals. They are not only found in birds, but in reptiles. The sea-turtle has what is termed a muscular stomach. Among fishes, the mullet and the gillaroo trout have muscular stomachs. The cuttle-fish, the nautilus, and even the earthworm, have a crop and gizzard; and insects, according as they live on a leaf or suck the blood, have the same difference in the internal arrangement of the structure for assimilation as that which distinguishes the ox from the lion.—ENG. ED.

ruder operation of the dog's teeth suit the delicate texture of the quills. The bill, therefore, implies the absence of teeth and of salivary glands. Lips and muscular cheeks are necessary for mastication; and, however familiar the operation may be, a chapter might be well occupied to show how cheeks and lips, salivary glands and teeth, must cooperate before a morsel can be swallowed, and how the derangement of one filament of the nerves supplying these parts, disorders the whole train of actions. We have to show, then, how this function, deficient in the bird, is compensated by internal structure.

The gizzard is a fleshy stomach, the exact substitute for the muscles of the jaws, and teeth. Its substance consists of a strong muscle; the dark part of the gizzard being the muscle, and the shining part of it the tendon to which the muscular fibres are attached. There are, in fact, two muscles with a central tendon; it is what anatomists call a digastric or double-bellied muscle. The cavity within this muscle is lined with a dense, rough, insensible coat, and there are always to be found contained in it small stones, generally of quartz, if it be within the reach of the creature's instinct to obtain them. The grains are mixed with these portions of stone; and if we put our ear close to a bird, we shall hear the grinding motions going on, as distinctly as the noise of the horse's jaws in the manger. In fact, this digastric muscle or gizzard is equivalent to the muscles of the jaws, and the pebbles are a fair equivalent to the teeth, with this advantage, that when they are ground down, the instinct of the bird supplies it with more. It picks up some small portions of gravel with as much alacrity as it will the grain itself. Some have supposed, that this was sheer stupidity in the fowl; but here, surely, instinct is better than reason.

When we recollect the provisions against attrition necessary to make the teeth last for the full period of the life of a graminivorous quadruped, we are prepared to understand the advantage of this beautiful and simple substitute, which, to so small a creature as a pigeon, gives an equal power over the material of its food, as the horse has with its *powerful jaws*, and strong grinding teeth.

However, we are but describing a new instrument for grinding, or comminuting the food: yet this alone is not sufficient to supply what was wanting in the mouth; and in passing, we may observe, that the gizzard does not exclusively belong to birds. The gillaroo trout and the mullet, have gizzards. The toothless ant-eater has a gizzard: it lives on scaly and hard insects, such as beetles; and to assist in bruising them in its muscular stomach, it picks up pebbles like the domestic fowl.

Before the grain descends into this grinding apparatus of the bird, it is deposited in the crop; from the crop it descends, by little and little, into the cardiac cavity, as the first part of the stomach is called. In this latter cavity, there are glands which secrete the gastric juice, and which fluid is necessary to digestion. We should here also note a particular provision in the upper orifice of the gizzard, namely, the overlapping of a part of the muscle, which produces an obliquity in the passage, and holds the contents of the stomach confined during the strong action of grinding. It was, indeed, at one time, supposed that such a mechanical operation of the stomach as we have described in the gizzard, fitted the food to supply the nourishment of the body; but, we repeat, that it has no further operation than that of comminuting the hard food, and preparing it for the action of this animal fluid, the gastric juice, which digests; and digestion is the first process of assimilation.

It may be interesting to the reader to know, that the lower orifice of the gizzard, where it opens into the first intestine, (*duodenum*,) is differently guarded in different families of birds. In birds which have abundance of food, the gizzard has no valve to retard its escape; so that a greater part of the grains or seeds on which they feed, passes off undigested. Were birds of prey furnished with the same grinding apparatus which is suited for birds that feed upon grain, our argument would be overturned. But in them the gizzard is very weak; the cuticular lining of the stomach very thin; and the gastric glands, which pour out the digesting fluid, very large. In the hawk and kite we find no such macerating crop as in the domestic fowl.

Our author states, that one class of birds cannot digest grain, the other cannot digest flesh. This, however, taken literally, does not accord with the experiments of Mr. Hunter, since he brought the carnivorous birds to live on grains, and the granivorous fowls to live on meat. But the necessity of accomplishing this change by very slow degrees, leaves the substance of our author's argument sustained.

It is presumable that animal and vegetable matter are, in their ultimate elements, nearly the same ; and, therefore, the last action of assimilation of the food is probably similar in all creatures. The variety of organization or structure in the stomach, will be found to depend on the proportion of nutritious matter in the mass that is swallowed. A vegetable feeder requires, from the poverty of its food, to be continually digesting ; and, happily, its food is in abundance around it. The carnivorous animal gorges its food, after long and irregular intervals ; its prey is precarious ; but then, that food is richer in nutritious matter, and requiring to undergo only the last process of assimilation. The variety and complication in the structure of the digestive organs depending on the nature of the food, are not only exhibited in quadrupeds and birds, but in fishes and in insects. Insects that suck blood have a simple canal : the grasshopper and white ant, vegetable feeders, have a complicated canal. Just for the same reason the intestines of the lion are short and wide, and those of the goat long and complicated.—SIR CHARLES BELL.]

III. But to proceed with our *compensations*. A very numerous and comprehensive tribe of terrestrial animals are entirely without feet, yet locomotive, and in a very considerable degree, swift in their motion. How is the *want of feet* compensated ? It is done by the disposition of the muscles and fibres of the trunk. In consequence of the just collocation, and by means of the joint action of longitudinal and annular fibres—that is to say, of strings and rings—the body and train of reptiles are capable of being reciprocally shortened and lengthened,

drawn up and stretched out. The result of this action is a progressive, and in some cases a rapid, movement of the whole body, in any direction to which the will of the animal determines it. The meanest creature is a collection of wonders. The play of the rings in an *earthworm*, as it crawls, the undulatory motion propagated along the body, the beards or prickles with which the annuli are armed, and which the animal can either shut up close to its body, or let out to lay hold of the roughness of the surface upon which it creeps, and the power arising from all these of changing its place and position, afford, when compared with the provisions for motion in other animals, proofs of new and appropriate mechanism. Suppose that we had never seen an animal move upon the ground without feet, and that the problem was: Muscular action, *i. e.*, reciprocal contraction and relaxation being given, to describe how such an animal might be constructed capable of voluntarily changing place. Something, perhaps, like the organization of reptiles might have been hit upon by the ingenuity of an artist; or might have been exhibited in an automaton, by the combination of springs, spiral wires, and ringlets; but, to the solution of the problem would not be denied, surely, the praise of invention and of successful thought: least of all could it ever be questioned whether intelligence had been employed about it or not.[52]

[52] Not unconnected with the subject of the last note is the progression of animals: and we have none better suited for the object of this volume than the consideration of the infinite variety of the instruments of motion, from the blubber that floats like froth upon the water, to the eagle or the antelope. The genus *medusa* of Linnæus embraces those animals like jelly which float in the sea. Some of these, when taken out of the water, will weigh fifty ounces, and, on being dried, not more than five or six grains. From this it would appear, that they must be of the specific gravity of water, and hence their peculiar organization and mode of existence; especially it accounts for their mode of progression, if it can be called so: since they are in a great measure passive, and float and are carried by the wind. For this purpose there is a vesicle or bladder filled with air, which in some rises above the water, and the animal is dragged, as we might imagine a balloon would be, after lighting on the water. The walls of this sac are muscular, and the animal, by retaining or forcing out the air, can either take advantage of the wind, and is sometimes moved with great velocity, or *sink under the* surface, and move only with the current. There is

every reason to believe that the air, which is the principal means of change of place, is secreted by the animal.

From some of these animals, tentacula hang down into the water for seizing their food, and perhaps for directing their progress. They have a power of distending them, or erecting them by forcing water into their texture, by the contraction of vesicles near their base. Varieties of these animals hoist a plate or crest out of the water, which has a still greater resemblance to a sail.

We have already noticed the fins of fishes, the wing of the bird, and the web-foot of the duck. "The meanest creature is, indeed, a collection of wonders." In the earthworm or the caterpillar, the head, or the anterior part of the body, is projected (and it is a difficult problem to produce extension by contraction) till it touches the ground, and slightly adheres to it, when the posterior part of the body is drawn forwards. In many worms or caterpillars, there are holders discoverable upon minute inspection, and their anatomy exhibits a perfect set of muscles attached to those exterior rough points ; by which it is made evident that each of them is a foot. But nothing is more interesting than, to see the change of the larva to the winged insect, where these muscles and their appropriate nerves disappear : and new muscles, and new nerves, and new energies direct the creature that crept an inch in an hour, to outstrip, as we have said, the fleetest horse, or to rise upon the wind ; for those who travel by the new railroads observe bees to fly round them, and therefore to move above sixty miles an hour. The contrasts are the most curious between the flight of the bat and the motion of the mole ; the same organization being calculated, with slight adaptation, for the atmosphere, and for moving under the earth. We might almost give the instance of the perforation of solid calcareous rock by the boring mollusca, which, by late observations, seems to be accomplished by means of the foot.—ENG. ED.

END OF FIRST VOLUME.